Results of a pan-European study on energy savings due to window replacement

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This report includes 137 pages including appendix. Publication of the results must not be incomplete or in a disfiguring context.

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Important notes

1. The present report covers assessments about heating energy and CO_2-emission savings due to window replacements in residential buildings.
2. Saving potentials are calculated by dynamic simulations on a building level for different buildings. Based on these building specific results, savings on a national level for different EU28-countries are derived by extrapolations using statistical data from different sources.
3. The study does not cover any assessments regarding cooling energy and thermal comfort in the summertime.
4. The data used for the calculations and extrapolations have been retrieved, handled and analysed to the best of the author’s ability and knowledge. Neither EuroWindoor nor IBH assume any liability from damages that may arise from the use of this report and its content.
5. Unless otherwise indicated in the text, all graphics and images have been created by Ingenieurbüro Prof. Dr. Hauser GmbH.

Content

1 Executive Summary

Around 25 % of energy consumption in Europe [1] is directly linked to the households sector, of which heating consumption in existing buildings accounts for approximately 70 % in central European countries (e.g. Germany with total energy consumption of 665 TWh with 462 TWh for room heating (69,5 %) [2]) or even more in northern European countries due to lower average outdoor temperatures in the heating period.

Thorough analysis shows that 57 % of the residential building stock was built before 1980 and a further 22 % was built between 1980 and 2000. [3]

There is great potential for the existing building stock to contribute to energy savings and the reduction of CO_2 emissions, while at the same time improve the indoor climate of the buildings.

It is therefore crucial to define cost-efficient renovation policies that can improve the performance of the existing building stock – both in terms of energy and indoor climate, and window replacement has a significant role to play in this.

The main purpose of this study is to demonstrate how window replacement policies (based on technical assumptions) can support energy savings while maintaining affordable solutions for end-users. This study also describes why the performance of windows should be evaluated not only due to their single thermal insulation performance – as usually addressed by building regulations – but also due to the free solar gains that come through them (energy balance approach).

Based on simulations carried out on representative European residential buildings, this study shows that window replacement significantly contributes to reducing energy consumption in Europe, provided that appropriate measures are taken to secure the performance of replacement windows.

Window replacement can easily save more than 15 % of the whole heating needs of the existing building stock. Furthermore, this significant contribution can more effectively be achieved if policies are based on energy balance requirements, by combining both minimum solar gains (=minimum solar factor “g-value”) and maximum heat losses (=maximum U_w-value) in an overall “energy-balance requirement”.

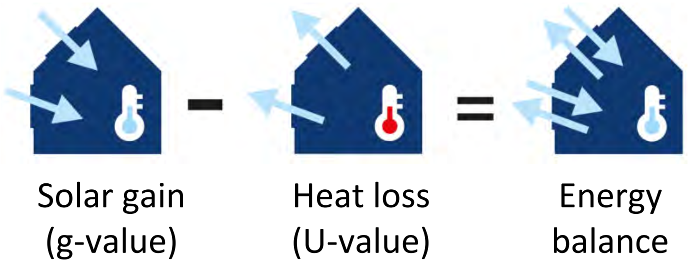

Figure 1-1: Energy balance approach

Most European countries today use technical requirements for window replacement based on the single U_W-value, whereas energy-balance requirements can save up to twice as much energy and CO_2.

This study shows that energy-balance requirements could save up to 280 TWh/year and up to 67 Mt CO_2/year across Europe if implemented in renovation policies for windows. Such an approach would also – in addition to securing that energy and CO_2 savings are achieved – stimulate innovation in the building industry, as target wouldn’t be set via a single parameter (U_w-value), but via a combination of parameters.

Energy balance requirements is giving a more accurate picture of a window’s performance to a building. Recommendations for the implementation of energy-balance requirements are provided at the end of the report. The key success criteria of implementing energy-balance requirements and securing the efficiency of window replacement policies are listed below:

- Window replacement policies based on single U_w-value requirements should be replaced by energy-balance requirements to optimise and secure their efficiency
- Energy-balance equations should be defined at national level to account for local climatic conditions, building traditions etc.
- Energy-balance requirements should be based on cost-optimality
- For cooling dominated countries, policies should include expectable savings for cooling as they account for a significant part of building consumptions

Finally, it should be highlighted that saving energy is only one of the drivers for replacing windows, but it is also – and maybe even to a higher extend - driven by e.g. getting more daylight, avoiding over-heating, updating design (incl. the visual expression of the building, safety and accessibility in use, protection against noise, burglar resistance etc.) and of course – but not least – cost considerations.

2 Introduction

To show how important the analysis of possible heating energy savings is, data about energy consumption in Germany shall be taken as an example. The overall energy consumption in Germany reached 2.542 terawatt hours (TWh) the year 2016 [4].

- About one quarter (26 %) of this belongs to households.
  The other three quarters are formed by shares of 28 % for industry, 16 % for trade, commerce and services and 30 % for traffic and transport. (see Figure 2-1)
- Around 70 percent of the households' energy demand is used for heating [2] (see Figure 2-2)
  This fraction of around 70 % for heating energy can be seen as typical fraction for central European countries, for northern European countries the part of energy consumption for heating is even higher due to normally lower outdoor temperatures in the heating period compared to central European countries.
- This means, that the energy consumption for heating in residential buildings reaches close to 20 percent (18,2 %) of the total energy consumption in Germany.

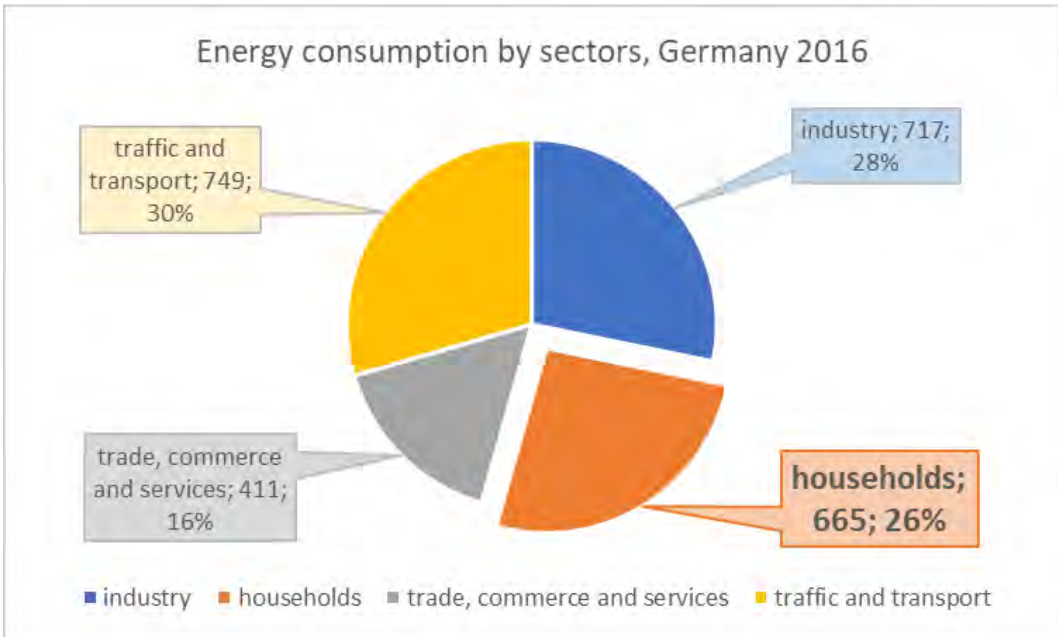

Figure 2-1: Energy consumption by sectors, Germany 2016 [4]

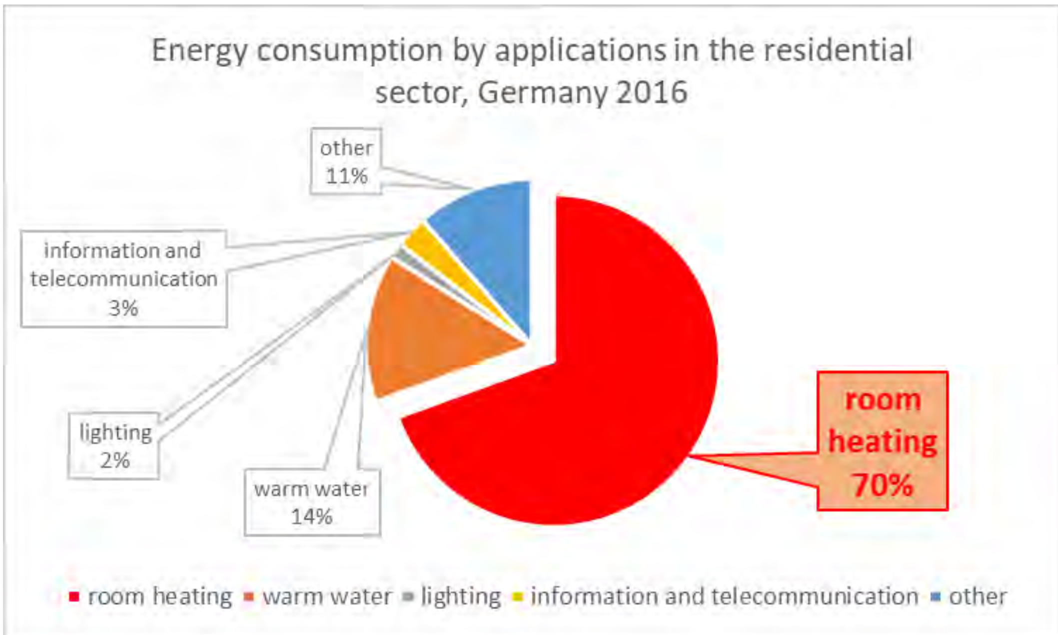

Figure 2-2: Energy consumption by application in the residential sector, Germany 2016 [2]

Especially because of the main energy consumption for heating is caused by the older building stock, the numbers above underline the necessity to analyze and quantify different saving potentials in the framework of building renovation where window replacement plays an important role. Therefore, the outcome of the study is on the one hand meant to support building owners and planners to "find" the right window for an individual renovation. On the other hand, the development of national requirement systems (at least for building renovation) shall profit from the results because of only requirements that take the energy balance of windows and not only transmission losses into account can lead to useful energy- and cost-efficient solutions. Actually, only some of the European countries have established requirements that fulfil such an integral approach.

The content of this report is devoted to the heating energy and CO_2-emission savings of residential buildings associated with window replacement in the course of renovations on a pan-European level. The study shall mainly show that only U_w-values as requirement values for the renovation case usually do not lead to the optimal energy performance for the renovated buildings because of only losses but not gains are described by this characteristic value. It is shown that using an energy-balance approach as for example developed and described in the framework of the pan European project "LOT 32 - Ecodesign Preparatory Study on Window Products" [5] is the most suitable way to express requirement values for window replacement rather than using only U_w-values.

3 Motivation, methodology and boundaries

Driven by conviction, that in requirement values for window replacement, where only heat losses (characteristic U_W-value) are taken into account, the significant impact of solar gains (characteristic g-value) is missing, the present study has been carried out. The outcome of the study is meant to show how the inclusion of solar gains in national requirements can help to optimize the energy performance of buildings with an energy balance approach (see Figure 1-1) and hereby ensure maximum saving potentials.

When talking about saving potentials for different renovation options for buildings envelopes or parts of the envelope, the principle seems to be quite easy to understand: the better the insulation level (e.g. the lower the U-values of single constructions) is, the lower is the resulting heating energy demand. This way of thinking has been established over the last decades and optimization of building energy performance worked quiet well with this principle also for windows for a long time. It also worked for windows because of improving the U_W-value while keeping the level of the g-value does in fact lead to energy savings. But this way of thinking has to be changed every time when improving the U-value goes along with (significant) reduction of the g-value. E.g. when improving the U-value means switching from 2-layer to 3-layer technology the losses of solar gains due to a lower g-value can have a higher impact compared to the energy savings due to a better U-value. Because of the general development of windows is actually at a point where further improvement of U-values do not necessarily lead to higher energy savings it is of high importance that the “old principles” are replaced by “up-to-date requirements” that include both: losses and gains of windows and other transparent parts of a buildings envelope.

The following Figure 3-1 gives an overview across EU Member States regarding the implementation of requirement systems for window replacement. It can be seen, that there are still a lot of countries with non-sufficient requirements that only focus on transmission losses. Especially countries with dominating heating energy consumption, such as northern and central European countries, could improve their requirements for window replacements and lead to more energy efficient concepts by establishing requirement systems that also take the solar gains into account.

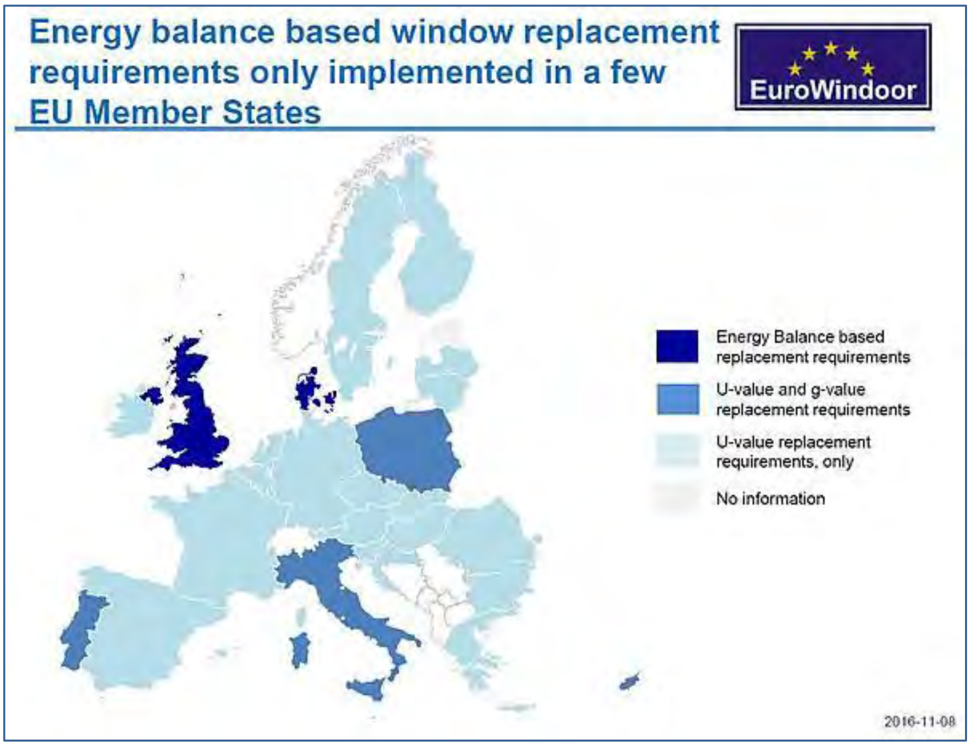

Figure 3-1: Overview about energy balance requirements for window replacement in the EU Member States [6], data basis: LOT 32, Task 1 [7]

This chapter is meant to describe the methodology as well as the calculations and its boundary conditions as basis for the derived results and extrapolations.

3.1 Methodology

As basis for the calculations in the frame of this study, dynamic simulations are done for different geometries of residential buildings on a net energy level. To keep it as simple as possible these simulation use building geometries that can be seen as typical representatives for the residential building stock. For further information about the simulation environment and the chosen building geometries is given in chapter 3.2.

The building specific simulation results on a net energy level are taken as basis for extrapolations on a national level. For extrapolations on a national level, country specific information about individual composition of the building stock is needed. Information about the country specific building stock has been taken out of the following two main sources:

1. Episcope building typology [8]
2. Data out of the framework of "LOT 32 - Ecodesign of Window Products" [9]

Further information about the used data out of [8] is provided in chapter 3.3.1. Due to the episcope-database does not provide full and comprehensive data about all EU Member States, additional data from LOT 32 - Task 7 [10] has been analysed and used for extrapolations on a national level. More information about the used data out of [10] is given in chapter 3.3.2.

Due to the climate itself is the main boundary condition when assessments about heating energy demand are in the focus, the simulations for this study are carried out by using individual climate data for each EU country. Knowing that national climate can vary in a wide range, the climate data of each countries capital has been used as simplification. For more information about the used climate data, please see chapter 3.4.

The useful amount of solar gains which reduce the heating demand of a building depends on the average insulation quality of a building. In order not to overweight the calculated saving potentials two different insulation qualities have been set. These two different insulation qualities are named "base case 1" (non or poorly renovated building) and "base case 2" (building moderately renovated). Detailed information about these base cases and its thermal qualities are given in chapter 3.5 together with information about the window qualities in these base cases. This chapter also gives information about the regarded renovation windows.

To derive information out of the aforementioned net energy results on a building level about energy saving potential on a final- and primary energy level as well as for corresponding saving potential regarding the CO_2-emissions, it is not only important to have information about the building stock, its composition regarding age and insulation level. Furthermore, it is very important to have information about the different heating systems, the efficiency of these systems and the used energy carriers. Such country specific data is also provided in the episcope database. The way, how this data has been used for extrapolations in this study is describes in chapter 3.6.

Following the general methodology as described above, for each country- the energy demands (net-, final, and primary energy demand) as well as the CO_2-demands and the saving potentials corresponding to window-renovation scenarios are calculated on a building level, taking into account different renovation window types with the U_W- and g-value varying in a broad range (see chapter 3.5). The set of renovation cases delivers a range of the saving potential due to window renovation on a building level, which makes it easy to point out the most energy-efficient scenario on a building level for each country. Together with additional information about the costs for different windows it is possible to find an optimum between energy and cost efficiency. Depending on what level the cost-efficiency shall be assessed, at least the investment costs and eventually further aspects, such as costs for installation and transportation have to be taken into account.

3.2 Simulation environment and geometrical modelling

Geometrical numerical modelling of representative buildings are taken as basis for dynamic simulation calculations with our software (HAUSer [11]). The calculations are done for a typical single-family-house (SFH, see sketch in Figure 3-2) and for two units in a typical multi-family-house (MFH, see sketch in Figure 3-3), geometry of both buildings taken out of [12].

Already existing numerical models for these buildings are taken and slightly modified in order to cover the intended scope of the study in the best way (variation of window fraction and distribution regarding façade, roof and orientation). The geometrical variation herby covers three different window-to-floor-ratios of 10, 20 and 30 %.

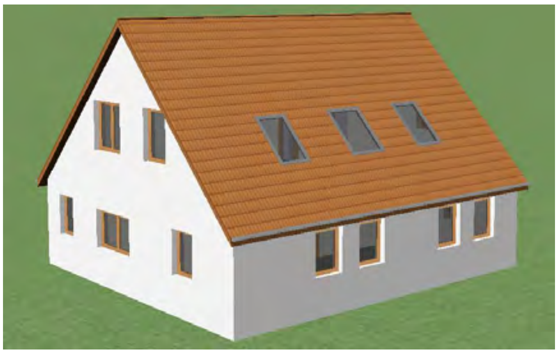

Figure 3-2: Sketch of single-family-house (SFH)

Figure 3-3: Sketch of living units in multi-family-house (MFH)

Together with the chosen energetic preferences for different base cases and renovation scenarios (see chapter 3.5) the parameter variation is set in a way, that all the main influencing parameters on savings due to window renovation in the building stock are covered as good as possible with regards to acceptable simplifications. One of these simplifications for this study is the limitation of calculations for the aforementioned two representative buildings. Especially with regards to the limited accuracy and availability of data about country specific building stocks, the simulation of more buildings would not lead to results of better quality. Compared to the variation buildings the influence of different window-to-floor-ratios as well as the variation of internal gains is of much higher importance regarding the calculated saving potentials. These influences are covered properly in the scope of this study as described in chapter 3.5. In addition to this and with regards to the goal to assess saving potentials due to window replacements, the calculated saving potentials are given for different replacement options while the remaining envelope is kept like described in the two base cases.

3.3 Building stock data

3.3.1 Source: IEE project EPISCOPE

The ***E***nergy ***P***erformance ***I***ndicator Tracking ***S***chemes for the ***C***ontinuous ***O***ptimisation of Refurbishment ***P***rocesses in ***E***uropean Housing Stocks or, for short EPISCOPE [8], is a follow-up project of the previous EU projects DATAMINE and TABULA and is co-funded by the programme Intelligent Energy Europe (IEE). The purpose of this project has been to create a greater transparency and efficiency in the energy saving processes of the European housing sector in order to attain the climate protection targets.

The EPISCOPE-Website provides information about the building stock for 21 European countries (see Table 3-1).

Table 3-1: European countries, EU Member States and episcope [8] participants

No.	Init.	Country	Capital	EU	episcope
1	AT	Austria	Vienna	yes	yes
2	BA	Bosnia Herzegovina	Sarajevo	no	yes
3	BE	Belgium	Brussels	yes	yes
4	BG	Bulgaria	Sofia	yes	yes
5	HR	Croatia	Zagreb	yes	no
6	CY	Cyprus	Nicosia	yes	yes
7	CZ	Czech Republic	Prague	yes	yes
8	DK	Denmark	Copenhagen	yes	yes
9	EE	Estonia	Tallinn	yes	no
10	FI	Finland	Helsinki	yes	no
11	FR	France	Paris	yes	yes
12	DE	Germany	Berlin	yes	yes
13	GR	Greece	Athens	yes	yes
14	HU	Hungary	Budapest	yes	yes
15	IE	Ireland	Dublin	yes	yes
16	IT	Italy	Rome	yes	yes
17	LV	Latvia	Riga	yes	no
18	LT	Lithuania	Vilnius	yes	no
19	LU	Luxembourg	Luxembourg	yes	no
20	MT	Malta	Valletta	yes	no
21	NL	Netherlands	Amsterdam	yes	yes
22	NO	Norway	Oslo	no	yes
23	PL	Poland	Warsaw	yes	yes
24	PT	Portugal	Lisbon	yes	no
25	RO	Romania	Bucharest	yes	no
26	RS	Serbia	Belgrade	no	yes
27	SK	Slovakia	Bratislava	yes	no
28	SI	Slovenia	Ljubljana	yes	yes
29	ES	Spain	Madrid	yes	yes
30	SE	Sweden	Stockholm	yes	yes
31	UK	United Kingdom	London	yes	yes

A close look into the episcope-database shows that the provided data contains detailed information about country specific building stock data distinguishing regarding age of building (insulating level of buildings envelopes) and type of building (different types of single-family and multi-family houses). Hereby the quality, accuracy and amount of available data varies from country to country.

The database contains further and more detailed information about typical construction elements and their U-values, information about the heat supply (see also chapter 3.6) and much more for each participating country.

While the aforementioned construction periods vary from country to country and will be described later in this chapter, the building typology includes the following four types:

- Single-family house (SFH)
- Terraced house (TH)
- Multi-family house (MFH)
- Apartment block (AB)

The calculations in the scope of this study is focused on one representative single-family house and two units of a multi-family house (see section 3.2). The limitation is a necessary and tolerable simplification for this study because of other boundary conditions such as the window-to-floor-ratio and the difference in internal gains is of much higher importance than additional calculations for other building geometries. The generated results and saving potentials derived out of the simulations are taken as specific results referring to m² usable area (German: Nutzfläche A_N). These specific savings are later used for the extrapolations on national level.

As mentioned before, the quality and accuracy of given data in the episcope database varies from country to country. Especially the given fractions for the different building types are not sufficient enough to derive country specific distributions regarding different building types for the individual construction periods. Due to the goal of this project is to derive energy saving potentials for all EU 28 member states, the data out of the episcope database is combined with country specific data out of the LOT 32 framework [5]. The final and consolidated report for Task 7 [10] in the LOT 32 framework provides country specific data for the useful area for all EU 28 members (further information is given in the next chapter 3.3.2). Especially because of the available country specific data about the individual usable are is also only available for the two categories SFH and MFH. Taking this into account the simulation of more building types or geometries would not lead to more accurate results. As third source regarding country specific building stock information, detailed information about age specific distribution of each countries building stock is taken out of the EU Buildings Database [3]. Further information about the used data out of this source is given in chapter 3.3.4.

In addition to country specific information regarding the different types of buildings in each country, the episcope database also provides information about age-dependant insulation qualities. A fundamental part of the study is an intensive research in the database to evaluate the quality of available data about insulation level and window quality. The episcope-database provides lots of relevant data, but only a few of the participating countries are covered in a way that the whole countries building stock is fully described. To keep the evaluation as simple as possible and as accurate as necessary, two different base cases are defined. Taking the energy demands of these two base cases, different renovation scenarios with different replacement windows are assessed. Further information about theses base cases and the renovation scenarios are content of chapter 3.5.

3.3.2 Source: LOT 32 Ecodesign Preparatory Study on Window Products

As basis for the extrapolations of savings on a national level data out of LOT 32 – Task 7 [10] is used. Herein the useful national floor area is given with the numbers shown in Table 3-2.

Table 3-2: Country specific useful floor area as given in LOT 32 – Task 7 [10]

No.	Country		floor area out of LOT 32 [10^6 m²]		
			SFH	MFH	Sum (SFH;MFH)
1	Austria	AT	279	153	432
2	Belgium	BE	440	69	509
3	Bulgaria	BG	140	108	248
4	Croatia	HR	127	49	177
5	Cyprus	CY	22	10	32
6	Czech Republic	CZ	220	169	389
7	Denmark	DK	278	99	377
8	Estonia	EE	18	28	46
9	Finland	FI	172	73	245
10	France	FR	1.840	891	2.732
11	Germany	DE	2.509	1.614	4.123
12	Greece	EL	148	253	401
13	Hungary	HU	300	87	387
14	Ireland	IE	224	15	239
15	Italy	IT	983	2.197	3.179
16	Latvia	LV	44	40	84
17	Lithuania	LT	67	62	129
18	Luxembourg	LU	14	7	21
19	Malta	MT	10	4	14
20	Netherlands	NL	726	87	812
21	Poland	PL	679	506	1.185
22	Portugal	PT	337	181	519
23	Romania	RO	391	184	575
24	Slovakia	SK	106	65	171
25	Slovenia	SI	34	30	65
26	Spain	ES	715	1.228	1.943
27	Sweden	SE	204	162	366
28	United Kingdom	UK	1.952	245	2.198

The useful floor area given in Table 3-2 describes the total country specific floor area. Due to this floor area includes also newer buildings that are not to be treated as potentially being renovated in the frame of this study, these absolute values are reduced to smaller numbers that match to the defined base cases. To derive proper factors for the two base cases distinguishing between SFH and MFH the detailed information out of the episcope database is used. The next chapter 3.3.4 explains how the LOT 32 data and the episcope data is combined to derive these country specific useful floor areas for extrapolation.

3.3.3 EU Buildings Database

The EU Buildings Database [3] provides a wide content of different country specific data. As relevant data to be used in this study the following content of the database is used:

1. fractions for SFH and MFH as parts of the whole building stock (columns for Building stock fraction SFH and fraction MFH in Table 3-3)
2. information about the distribution of the building stock regarding different construction periods with assignment to the construction periods for base case 1 and base case 2 (time period fractions for the building stock in Table 3-3)

Table 3-3: Fractions for SFH and MFH and time period specific information [3]

No.	Country		Building Stock		time periods base case 1				time periods base case 2			*time periods newer buildungs*	
			fraction SFH	**fraction MFH**	< 1945	1945-1969	1970-1979	**sum for base case 1**	1980-1989	1990-1999	**sum for base case 2**	*2000-2010*	*>2010*
1	Austria	AT	**63%**	**37%**	27%	19%	13%	**59%**	12%	13%	**25%**	*12%*	*5%*
2	Belgium	BE	**81%**	**19%**	34%	25%	12%	**71%**	9%	8%	**17%**	*9%*	*3%*
3	Bulgaria	BG	**55%**	**45%**	19%	32%	15%	**67%**	12%	6%	**18%**	*2%*	*14%*
4	Croatia	HR	**66%**	**34%**	13%	27%	20%	**60%**	17%	9%	**26%**	*9%*	*5%*
5	Cyprus	CY	**64%**	**36%**	3%	10%	13%	**26%**	19%	17%	**36%**	*29%*	*8%*
6	Czech Republic	CZ	**57%**	**43%**	22%	22%	18%	**62%**	16%	10%	**26%**	*10%*	*2%*
7	Denmark	DK	**72%**	**28%**	32%	27%	17%	**76%**	9%	5%	**15%**	*8%*	*1%*
8	Estonia	EE	**37%**	**63%**	17%	27%	20%	**64%**	20%	6%	**25%**	*8%*	*2%*
9	Finland	FI	**55%**	**45%**	12%	21%	20%	**54%**	18%	12%	**30%**	*11%*	*5%*
10	France	FR	**68%**	**32%**	27%	18%	16%	**60%**	12%	10%	**22%**	*13%*	*4%*
11	Germany	DE	**60%**	**40%**	25%	34%	15%	**74%**	11%	8%	**19%**	*5%*	*2%*
12	Greece	EL	**34%**	**66%**	7%	24%	21%	**52%**	17%	13%	**30%**	*15%*	*4%*
13	Hungary	HU	**71%**	**29%**	25%	30%	12%	**68%**	12%	8%	**20%**	*9%*	*3%*
14	Ireland	IE	**87%**	**13%**	19%	14%	12%	**45%**	10%	13%	**23%**	*24%*	*8%*
15	Italy	IT	**27%**	**73%**	20%	31%	18%	**69%**	13%	8%	**20%**	*8%*	*3%*
16	Latvia	LV	**55%**	**45%**	23%	25%	20%	**67%**	20%	6%	**26%**	*5%*	*2%*
17	Lithuania	LT	**55%**	**45%**	22%	37%	17%	**76%**	13%	7%	**20%**	*3%*	*1%*
18	Luxembourg	LU	**71%**	**29%**	19%	19%	11%	**49%**	9%	12%	**21%**	*14%*	*15%*
19	Malta	MT	**66%**	**34%**	17%	17%	14%	**48%**	15%	14%	**29%**	*12%*	*12%*
20	Netherlands	NL	**81%**	**19%**	19%	24%	16%	**59%**	14%	12%	**26%**	*10%*	*4%*
21	Poland	PL	**33%**	**67%**	19%	23%	16%	**58%**	17%	12%	**28%**	*8%*	*6%*
22	Portugal	PT	**63%**	**37%**	16%	21%	14%	**52%**	16%	16%	**32%**	*16%*	*1%*
23	Romania	RO	**63%**	**37%**	11%	37%	19%	**67%**	15%	7%	**22%**	*8%*	*3%*
24	Slovakia	SK	**62%**	**38%**	14%	32%	23%	**70%**	18%	5%	**23%**	*6%*	*2%*
25	Slovenia	SI	**72%**	**28%**	30%	21%	18%	**70%**	11%	10%	**21%**	*7%*	*2%*
26	Spain	ES	**29%**	**71%**	13%	19%	17%	**49%**	13%	14%	**27%**	*17%*	*7%*
27	Sweden	SE	**59%**	**41%**	26%	34%	16%	**77%**	10%	6%	**16%**	*6%*	*2%*
28	United Kingdom	UK	**87%**	**13%**	37%	25%	13%	**75%**	9%	6%	**15%**	*6%*	*3%*

3.3.4 Combination of episcope, LOT 32 and EU Buildings database for national extrapolations

The episcope database provides detailed and accurate information about country specific fractions for individual construction periods and distinguishing between different building types (SFH and MFH) only for 7 European countries (Denmark, Germany, Greece, Netherlands, Norway, Slovenia and United Kingdom). For these countries the episcope database provides fractions for single-family-houses and multi-family-houses for three different construction periods 1, 2 and 3. Hereby the construction periods 1 and 2 match with the defines base cases 1 and 2, which are defined for the assessments in the frame of this study. To be able to extrapolate the simulation results generated on the building levels for SFH and MFH for the defined base cases it was necessary to fill the lack of country specific fractions regarding the distribution of the floor area with a proper approach. This was realized as describe in the following

- The first step is the definition of the three European climate regions North, Central and South together with a classification for each country to one of these regions.
- For each climate region North, Central and South a suitable representant is chosen as follows
  # North: Norway
  # Central: Germany
  # South: Greece
  These representants are only used to assign final and primary energy factors as well as specific CO_2-emission data for countries that do not provide individual national data. In this case the data of the representant is used.

- The detailed and climate region specific fractions of useful floor areas for single-family-houses as well as for multi-family-houses (construction periods 1 and 2 for SFH and MFH) out of the EU Buildings Database [3] are used to derive useful floor area for the categories SFH 1 (single-family house base case 1), SFH 2 (single-family house, base case 2), MFH 1 (multi-family house base case 1) and MFH 2 (multi-family house, base case 2) on the basis of the total floor are given in LOT 32 [10] (see Table 3-2). Hereby each country's individual floor area is multiplied with the fractions displayed in Table 3-3.

The individual and country specific useful areas as result of the methodology described above is given in Table 3-4.

Table 3-4: Derived useful floor areas for SFH and MFH and the two base cases for national extrapolations

No.	Country		derived national floor area (10^6 m²)			
			SFH base 1	SFH base 2	MFH base 1	MFH base 2
1	Austria	AT	161	68	93	39
2	Belgium	BE	291	71	68	17
3	Bulgaria	BG	90	24	74	20
4	Croatia	HR	70	30	36	16
5	Cyprus	CY	5	7	3	4
6	Czech Republic	CZ	137	58	105	44
7	Denmark	DK	207	39	81	15
8	Estonia	EE	11	4	19	7
9	Finland	FI	73	40	60	33
10	France	FR	1130	416	521	192
11	Germany	DE	1831	460	1231	309
12	Greece	EL	71	40	138	78
13	Hungary	HU	186	54	77	22
14	Ireland	IE	93	48	14	7
15	Italy	IT	599	179	1584	472
16	Latvia	LV	31	12	26	10
17	Lithuania	LT	54	14	44	12
18	Luxembourg	LU	7	3	3	1
19	Malta	MT	4	3	2	1
20	Netherlands	NL	392	174	91	41
21	Poland	PL	228	110	462	224
22	Portugal	PT	170	104	99	60
23	Romania	RO	245	80	142	47
24	Slovakia	SK	74	24	46	15
25	Slovenia	SI	33	10	12	4
26	Spain	ES	277	155	672	376
27	Sweden	SE	165	35	116	24
28	United Kingdom	UK	1440	290	210	42

3.4 Meteorological data

The meteorological data for the country specific calculations is generated with the software Meteonorm (version V 7.2). For each country the climate data of its capital was generated and used for the simulations. Table B-1 in Appendix B provides some relevant information about the generated climate files.

3.5 Thermal quality of the envelope and parameter variation for renovation scenarios

To declare base cases -for which different renovation scenarios can be assessed afterwards- an intensive research in the episcope database was done. The information about the insulation quality for different construction periods vary from country to country. Figure B-1 in Appendix B gives a rough overview about the available information. With regards to the available data about the distribution of the useful floor area (see chapter 3.3) two base cases for different renovation scenarios are defined. Hereby base case 1 is meant to describe non or poorly renovated older buildings. Base case 2 shall describe moderately renovated buildings where further renovation would still have a remarkable effect for the energy demand. The methodology regarding the definition of the named two base cases is described in chapter 3.5.1.

In addition to the description of the envelopes for the two base cases the renovation scenarios (different window types) are defined and described in chapter 3.5.2.

3.5.1 Definition of base cases – buildings envelope U-values (except windows)

The episcope database provides country-specific constructions and the corresponding U-values for reference buildings for different periods. Detailed information about these country specific U-values are given in Appendix B, chapter B 3 and for the time periods belonging to the two base cases (Table B-2 for base case 1 and Table B-3 for base case 2).

In order to avoid an unnecessary complexity and as a consequence of the similarity between the U-values of listed in Table B-2 and Table B-3 appropriate U-values are defined to describe the two different insulation levels to be used for all EU countries as base case 1 and base case 2 as given in Table 3-5. Thus, base case 1 shall correspond with a house which was built between 1970 and 1980 or poorly renovated older buildings. To consider younger buildings or older buildings that are already moderately renovated, base case 2 is defined.

Table 3-5: Defined U-values for the two base cases

	U-value [W/(m²·K)]	
	base case 1	**base case 2**
roof	0,80	0,36
wall	1,1	0,46
floor	1,0	0,65
ceiling (attic)	0,61	0,33
door	3,0	3,0

As an effect of the different building standards in different regions of Europe it is comprehensible that these generalized values do not exactly represent the U-values of the constructions in all 28 EU countries. The countries in Southern Europe (e.g. Cyprus) exhibit much higher values than the countries in the North, which have significantly lower U-values (e.g. Sweden). Keeping these differences in mind, the goal of this project is to derive average assessments regarding saving potentials. When it comes to detailed planning of individual houses, the given results on the basis of the described simplification can serve a rough estimation about saving potentials but not replace individual consulting service.

3.5.2 Regarded window properties

As possible renovation scenarios different window types have been fixed with U_w -values given in Table 3-6. For each U_W-value three different g-values of 0.60, 0.50 and 0.40 are calculated. For all window-types a frame-fraction of f_F = 0.30 is assumed. Regarding this theoretical parameter bandwidth, it has to be mentioned, that for g-values higher than 0.55 the technical feasibilities are limited in case of 3-layer glazing. This has to be taken into account when interpreting the saving potentials. As base case window for both base cases a window with U = 2,8 W/(m²K) and g = 0,76 is assumed.

Table 3-6: U_w-values for base case and renovation scenarios

<table>
<tr><th rowspan="2"></th><th rowspan="2">base case (1+2)</th><th colspan="7">renovation window</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>U_w [W/(m²·K)]</td><td>2,8</td><td>1,4</td><td>1,3</td><td>1,2</td><td>1,1</td><td>1,0</td><td>0,90</td><td>0,80</td></tr>
<tr><td rowspan="2">type</td><td rowspan="2">double layer without coating</td><td colspan="4">← double layer with coating →</td><td colspan="3"></td></tr>
<tr><td colspan="3"></td><td colspan="4">← triple layer with coating →</td></tr>
</table>

3.6 Assumptions about typical technical equipment and calculation of final- and primary energy consumption and extrapolation of CO_2-emissions

Simulation calculations are carried out on a net-energy level. For the calculation of final- and primary-energy level, typical specific values which describe country specific technical equipment (and corresponding efficiency ratios of the systems) are assumed on the basis of the episcope database [8]. These assumptions are also used to derive the CO_2-saving potentials as described later in this report.

The episcope database provides the needed data only for six countries (Germany, Great Britain, Greece, Netherlands, Norway and Slovenia) on a national basis. Therefore, the calculations for final- and primary energy consumption as well as extrapolations regarding CO_2-emissions for the remaining EU 28 members have to be developed on the basis of the available data. As an example, Table 3-8 shows the occurrences or fractions of produced heat for different heating systems for Germany. The related energy expenditure factors are given in Table 3-9. To better understand the content of Table 3-8 and Table 3-9 the herein used abbreviations are explained in Table 3-7.

Table 3-7: Abbreviations used in Table 3-8 and Table 3-9

Shortcut	Meaning
TS	Heat exchanger
B	Boiler
B_NC_CT	Standard boiler
B_NC_LT	Low temperature boiler
B_NC	Other boiler
B_WP	Woodpellet-boiler
B_C	Old condensation gas boiler
HP	Other heat pumps
HP_Air	Heat pump external air
HP_ExhAir	Heat pump extracted air
HP_Water	Heat pump ground water
HP_Ground	Heat pump soil
G_SH	Gas decentral heater
Stove_L	Liquid fuel stove
Stove_S	Wood stove
E	
E_Immersion	Electric Stove, immersed in a water storage
E_SH	
E_Storage	Night-storange heater
Vent_Rec	Ventilation with heat recovery
Solar	Solar panels
OpenFire	Fireplace

Table 3-8: Occurrences or fractions of produced heat for Germany, data out of [8]

			energy expenditure / final energy factor					
	heating systems		SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
1	District Heating	TS	0,01	0,02	0,03	0,12	0,22	0,11
2	Gas	B_NC_LT	0,41	0,43	0,59	0,51	0,61	0,76
3	Oil	B_NC_LT	0,37	0,37	0,17	0,25	0,13	0,05
4	Bio	B_WP	0,04	0,03	0,03	0,02	0,00	0,03
5	El	HP_Air	0,01	0,02	0,05	0,01	0,00	0,01
6	Gas	G_SH	0,01	0,00	0,00	0,01	0,00	0,00
7	Oil	Stove_L	0,01	0,00	0,00	0,01	0,00	0,00
8	Bio	Stove_S	0,04	0,00	0,01	0,01	0,00	0,00
9	Coal	Stove_S	0,01	0,00	0,00	0,01	0,00	0,00
10	El	E_SH	0,03	0,03	0,01	0,02	0,02	0,00
11	Bio_Wood	Stove_S	0,06	0,08	0,07	0,02	0,01	0,01
12	El	Vent_Rec	0,01	0,02	0,03	0,00	0,00	0,01
13	-	Solar	0,00	0,00	0,01	0,00	0,00	0,01

Table 3-9: Energy expenditure factors (final energy factors) of heat-generators in Germany, data out of [8]

energy expenditure / final energy factor

	heating systems		SFH I	SFH II	SFH III	MFH I	MFH II	MFH III
1	DH	TS	1,02	1,02	1,02	1,02	1,02	1,02
2	Gas	B_NC_LT	1,23	1,23	1,23	1,18	1,18	1,18
3	Oil	B_NC_LT	1,29	1,29	1,29	1,18	1,18	1,18
4	Bio	B_WP	1,37	1,37	1,37	1,25	1,25	1,25
5	El	HP_Air	0,35	0,35	0,35	0,35	0,35	0,35
6	Gas	G_SH	1,40	1,40	1,40	1,40	1,40	1,40
7	Oil	Stove_L	1,40	1,40	1,40	1,40	1,40	1,40
8	Bio	Stove_S	1,60	1,60	1,60	1,60	1,60	1,60
9	Coal	Stove_S	1,60	1,60	1,60	1,60	1,60	1,60
10	El	E_SH	1,00	1,00	1,00	1,00	1,00	1,00
11	Bio_Wood	Stove_S	1,60	1,60	1,60	1,60	1,60	1,60
12	El	Vent_Rec	0,10	0,10	0,10	0,10	0,10	0,10
13	-	Solar	0,00	0,00	0,00	0,00	0,00	0,00

The data above is used to derive country specific average final energy factors. Weighted by the occurrences in Table 3-8 and with regards to the corresponding final energy factors in Table 3-9 the average final energy factors for German heat supply in residential buildings is given in the following Table 3-10. Herein the factors are given for SFH I to SFH III as well as for MFH I to MFH III where the numbers “I” to “III” stand for different construction periods. Construction period “I” refers to the defined base case 1 and period “II” refers to the defined base case 2. Period “III” describes factors for newer buildings which are not covered in this study.

Table 3-10: Averaged and weighted final energy factors for Germany

	SFH I	SFH II	(SFH III)	MFH I	MFH II	(MFH III)
averaged and weighted final energy factor:	**1,27**	**1,24**	**(1,17)**	**1,16**	**1,14**	**(1,14)**

The calculation of country-specific primary energy factors (PEFs) is done following a comparable methodology. Together with the country specific final energy factors the primary energy factors for all treated European countries are given in Appendix B, chapter B 4, Table B-4. Herein the individual data for the six countries with sufficient data in the episcope database have their individual values. To fill the lack of data concerning the remaining countries, the final and primary energy factors of the representants for Northern, Central and Southern region (see Table 3-11) is used.

Table 3-11: Representants for North, Central and Southern European countries

part of Europe	representative climate
North	Norway (Oslo)
Central	Germany (Berlin)
South	Greece (Athens)

Also given in Table B-4 in Appendix B are the specific CO_2-emissions. Countries for which individual specific emissions are available are calculated with their individual values. In case of missing data, the average of the available emissions (0,230 kg/kWh) is assumed.

3.7 Country specific window area

For useful and reliable estimations on the basis of calculated values for energy savings in Europe it is essential to have values for the total, country specific window area. Because of such data does not exist, an average window to floor ratio of 20 % is assumed for all national extrapolations regarding savings of energy and CO_2-emissions. This assumption corresponds to the assumption described in LOT 32 [10].

Table 3-12: Window area referring to the defined base cases 1 and 2 for SFH and MFH

No.	Country		window area (10^6 m²)						
			SFH base 1	SFH base 2	MFH base 1	MFH base 2	Sum of SFH/MFH Base 1/2	% of total national window area	total national window area
1	Austria	AT	32	14	19	8	72	84%	86
2	Belgium	BE	58	14	14	3	89	88%	102
3	Bulgaria	BG	18	5	15	4	42	84%	50
4	Croatia	HR	14	6	7	3	30	86%	35
5	Cyprus	CY	1	1	1	1	4	63%	6
6	Czech Republic	CZ	27	12	21	9	69	88%	78
7	Denmark	DK	41	8	16	3	68	91%	75
8	Estonia	EE	2	1	4	1	8	90%	9
9	Finland	FI	15	8	12	7	41	84%	49
10	France	FR	226	83	104	38	452	83%	546
11	Germany	DE	366	92	246	62	766	93%	825
12	Greece	EL	14	8	28	16	66	82%	80
13	Hungary	HU	37	11	15	4	68	87%	77
14	Ireland	IE	19	10	3	1	32	68%	48
15	Italy	IT	120	36	317	94	567	89%	636
16	Latvia	LV	6	2	5	2	16	93%	17
17	Lithuania	LT	11	3	9	2	25	96%	26
18	Luxembourg	LU	1	1	1	0	3	71%	4
19	Malta	MT	1	1	0	0	2	76%	3
20	Netherlands	NL	78	35	18	8	139	86%	162
21	Poland	PL	46	22	92	45	205	86%	237
22	Portugal	PT	34	21	20	12	87	83%	104
23	Romania	RO	49	16	28	9	103	89%	115
24	Slovakia	SK	15	5	9	3	32	93%	34
25	Slovenia	SI	7	2	2	1	12	91%	13
26	Spain	ES	55	31	134	75	296	76%	389
27	Sweden	SE	33	7	23	5	68	93%	73
28	United Kingdom	UK	288	58	42	8	396	90%	440

The given values are the results of different assumptions, which are described in the text above. Therefore, it is important to check their validity by comparing them with other studies. The 'Housing Statistics in the European Union 2010' from 'The Hague: Ministry of the Interior and Kingdom Relations' seems to be an appropriate report for the purpose of comparing the characteristic numbers.

Here it is important to keep in mind, that their figures for the floor area are based on a 'usable area' level. In accordance with DIN 227 the nomenclature of the floor area is defined as in Figure 3-4. The 'Gross floor area' consists of the 'Construction area' and the 'Net floor area', while the latter then again is composed of the useable, the service, the circulation and the residual area.

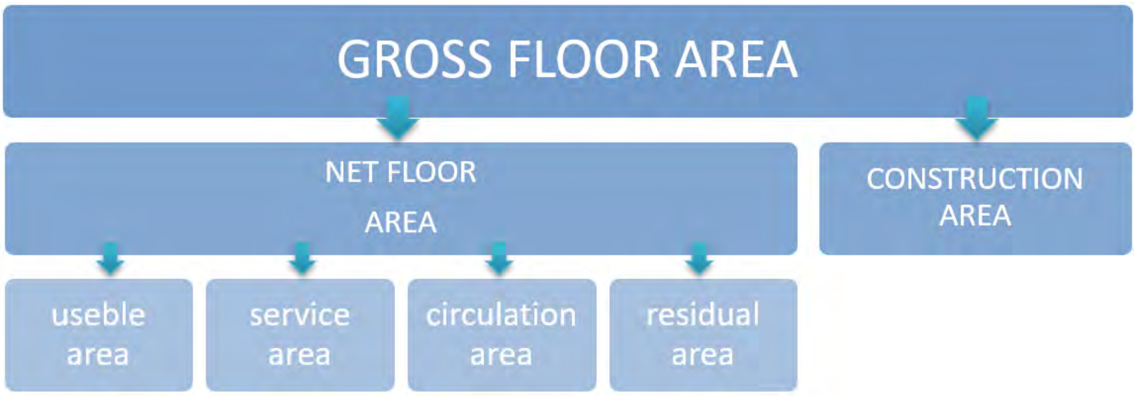

Figure 3-4: Definition of different floor areas [13]

The net floor area is the referring area in the scope of this study. Hereby it is comprehensible that the derived values are slightly higher than the values in the 'Housing Statistics in the European Union 2010'-report. Because of the net floor area is the are used for the simulation calculations, is has been decided to use the floor area as given in LOT 32. Table 3-13 shows the different values from different sources so that an easy comparability is possible.

Table 3-13: Deviations in floor area between different sources

Floor area [10^6 m^2]												
EU countries	No. of inhabitants	Percentage of EU population	Estimation		Episcope			EU Housing stock (useful f.a.)		LOT 32		
			calc. net f.a.	av.	total ref. area	calc. net f.a.	av.	calc. f.a.	av.	from LOT32 [m^2]	calc. net f.a.	calc. av.
Austria	8.623.073	1,7%	345	40	383	393	46	370	43	431.773.000	432	50
Belgium	11.358.952	2,2%	454	40	-	-	-	-	n.a.	509.152.000	509	45
Bulgaria	7.202.198	1,4%	288	40	-	-	-	181	25	247.937.000	248	34
Croatia	4.267.558	0,8%	171	40	-	-	-	-	-	176.525.000	177	41
Cyprus	858.000	0,2%	34	40	-	-	-	-	n.a.	32.095.000	32	37
Czech Republic	10.537.818	2,1%	422	40	-	-	-	302	29	389.145.000	389	37
Denmark	5.678.348	1,1%	227	40	-	-	-	292	51	377.360.000	377	66
Estonia	1.315.635	0,3%	53	40	-	-	-	39	30	46.377.000	46	35
Finland	5.479.018	1,1%	219	40	-	-	-	213	39	245.058.000	245	45
France	64.859.000	12,7%	2.594	40	-	-	-	2.588	40	2.731.512.000	2.732	42
Germany	82.800.000	16,3%	3.312	40	3.500	3.813	46	3.552	43	4.122.924.000	4.123	50
Greece	10.816.286	2,1%	433	40	480	481	44	331	31	400.523.000	401	37
Hungary	9.855.571	1,9%	394	40	-	-	-	307	31	387.183.000	387	39
Ireland	4.609.600	0,9%	184	40	-	-	-	161	35	238.571.000	239	52
Italy	60.734.190	11,9%	2.429	40	-	-	-	2.217	37	3.179.431.000	3.179	52
Latvia	1.978.300	0,4%	79	40	-	-	-	53	27	83.983.000	84	42
Lithuania	2.888.582	0,6%	116	40	-	-	-	72	25	129.205.000	129	45
Luxembourg	562.958	0,1%	23	40	-	-	-	37	66	20.682.000	21	37
Malta	417.432	0,1%	17	40	-	-	-	14	34	13.921.000	14	33
Netherlands	16.976.281	3,3%	679	40	724	736	43	696	41	812.378.000	812	48
Norway	5.267.146	-	211	40	244	252	48	-	-	-	-	-
Poland	38.484.000	7,6%	1.539	40	-	-	-	931	24	1.184.864.000	1.185	31
Portugal	10.374.822	2,0%	415	40	-	-	-	-	n.a.	518.727.000	519	50
Romania	19.942.642	3,9%	798	40	-	-	-	299	15	575.032.000	575	29
Serbia	7.058.322	-	282	40	-	-	-	-	-	-	-	-
Slovakia	5.421.329	1,1%	217	40	-	-	-	141	26	171.051.000	171	32
Slovenia	2.062.874	0,4%	83	40	65	67	32	64	31	64.654.000	65	31
Spain	46.439.864	9,1%	1.858	40	-	-	-	1.533	33	1.942.811.000	1.943	42
Sweden	9.804.082	1,9%	392	40	-	-	-	443	45	366.032.000	366	37
United Kingdom	64.596.800	12,7%	2.584	40	2.100	2.512	39	2.842	44	2.197.590.000	2.198	34
all countries	**521.270.681**		**20.851**	-	-	**22.231**	-	**18.347**	-	**21.596.497.000**	**21.596**	**41**
MEAN	-		-	**40**	-	-	**43**	-	**35**	-	-	**41**

3.8 Relevance, accordance and optimization potential compared to the outcome of LOT 32

LOT 32 [9] provides a very detailed study on the Ecodesign of Window Products. Regarding windows in the frame of heating- or cooling-demand of a building, the outcome is, that for a correct evaluation of the energy-demand an energy-balance-method has to be applied. For heating and cooling the U_W- and g-value are the technical window characteristics with the most important impact.

LOT 32 explored the possibilities of developing an EU energy label for windows. However, no action has been taken as there was no broad support to such scheme due to – among others – significant differences between markets and climate conditions. Having that in mind there was on the other hand large support to show and underline that an energy balance approach is more than necessary to bring national requirements regarding window replacement into a direction where the requirement provides a more proper assessment of a window's contribution to a buildings' energy consumption. So, in addition to the outcome of LOT 32 the present study shall deliver another clear view on this and show the potential behind requirement systems that take both losses and gains into account.

An energy-balance for a window using U_W and g can be formulated on a steady-state level using "weighting-factors" for each of them. The weighting factors describe non-window-relevant impacts on the heating- or cooling demand such as "climate", "utilisation" and others. LOT 32 gives different approaches to build up such a steady-state-approach, but in each case the determination of the weighting-factors is in need of calculating the energy demand by a dynamic ("non-stead-state") method.

In the frame of this study such a dynamic method on an hourly basis - firstly described in [11] - was applied right from the beginning. Due to that all calculations are done with individual country specific climate data, there is no need to determine weighting-factors for each country or building. Furthermore, it can be underlined that energy balance performances of windows vary a lot from country to country.

Nevertheless, the conclusions from the consultation forum of LOT 32, hold in September 2015, demonstrated that a unified European approach (with 3 climatic zones only) for energy labelling is not relevant due to e.g. significant variations in climatic conditions. Therefore, when energy policies are based on energy balance, it has to be at national level to allow local conditions and specific market to be considered.

4 Results

This chapter provides results for the three levels “building”, “national” and “EU 28”. Hereby savings are given net-energy, final-energy and CO_2 emission. It has to be underlined that this study assesses only saving potential regarding the heating demand. The influence energy demand for cooling or thermal comfort assessment is not content of this study.

4.1 Savings on a building level

4.1.1 Net energy

On the building level, the results are calculated with the national climate for each country (climate data for the capital of each country as simplification).

As an example, in Figure 4-1 the net-energy demand for a single-family house with thermal insulation levels corresponding to base case 1 (grey bars with base case window U_W = 2,8 W/(m²K); g = 0,76) together with the energy demand resulting for the two different window replacements situations

1. renovation window with U_W = 1,3 W/(m²K) and a g-value g = 0,60 (green bars) and
2. renovation window with U_W = 1,1 W/(m²K) and a g-value g = 0,50 (purple bars).

is shown.

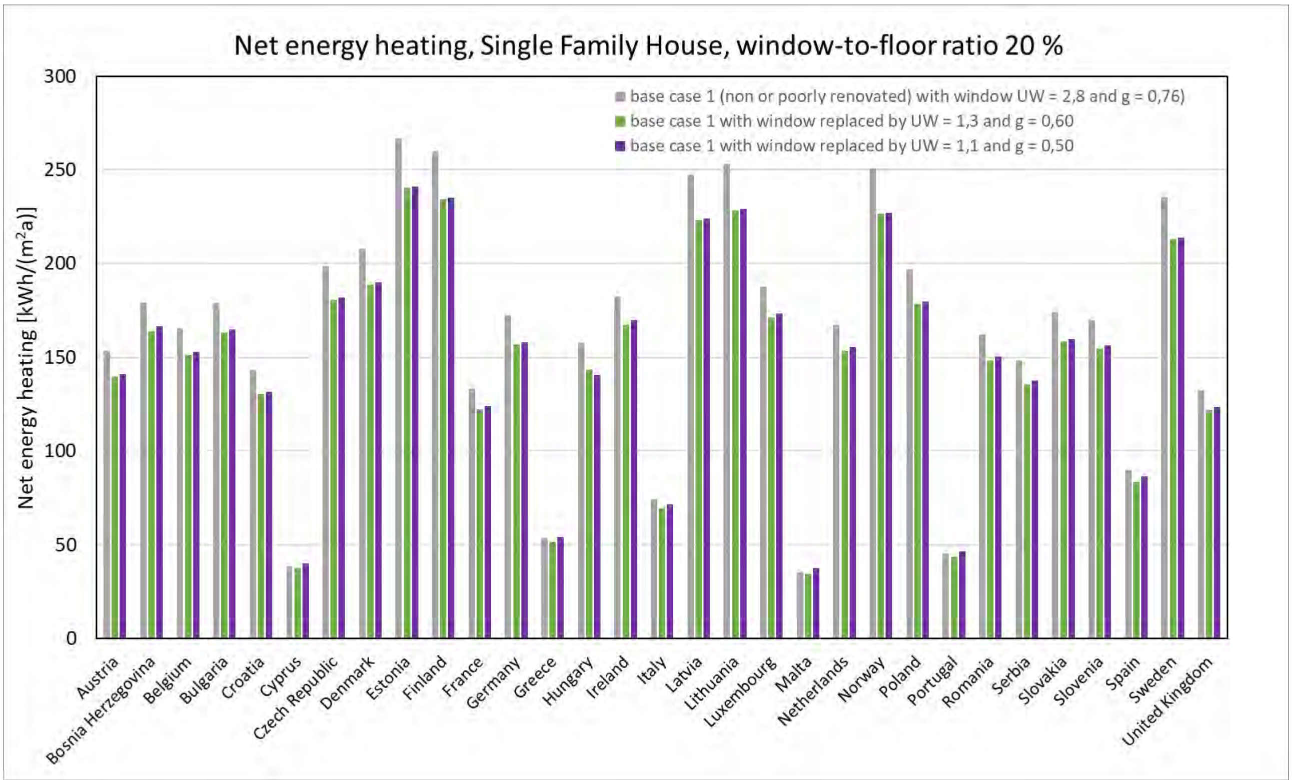

Figure 4-1: Net-energy demand for a single-family house with a thermal insulation level corresponding to base case 1 (blue bars) and a window-to-floor ratio of 20 % and for the renovated case with U_W = 1,3 W/(m²K) and g = 0,60 (green bars)

The net energy demands in Figure 4-1 clearly show that window replacement leads to significant savings in northern and central European climate while in southern European climate the energy demands do not show saving potentials. It has to be underlined that the given results stand for the energy demand in each countries’ capitals. This means that southern countries where the altitude varies from sea level up to areas high in the mountains, as for example in northern Portugal and northern Italy, there is also saving potentials which cannot be shown by using only one climate file per country. To assess saving potentials more detailed for each country and the different altitudes the variation of national climate has to be taken into account).

For the two renovation windows compared to the base case window the savings in net energy are separately shown in the following Figure 4-2.

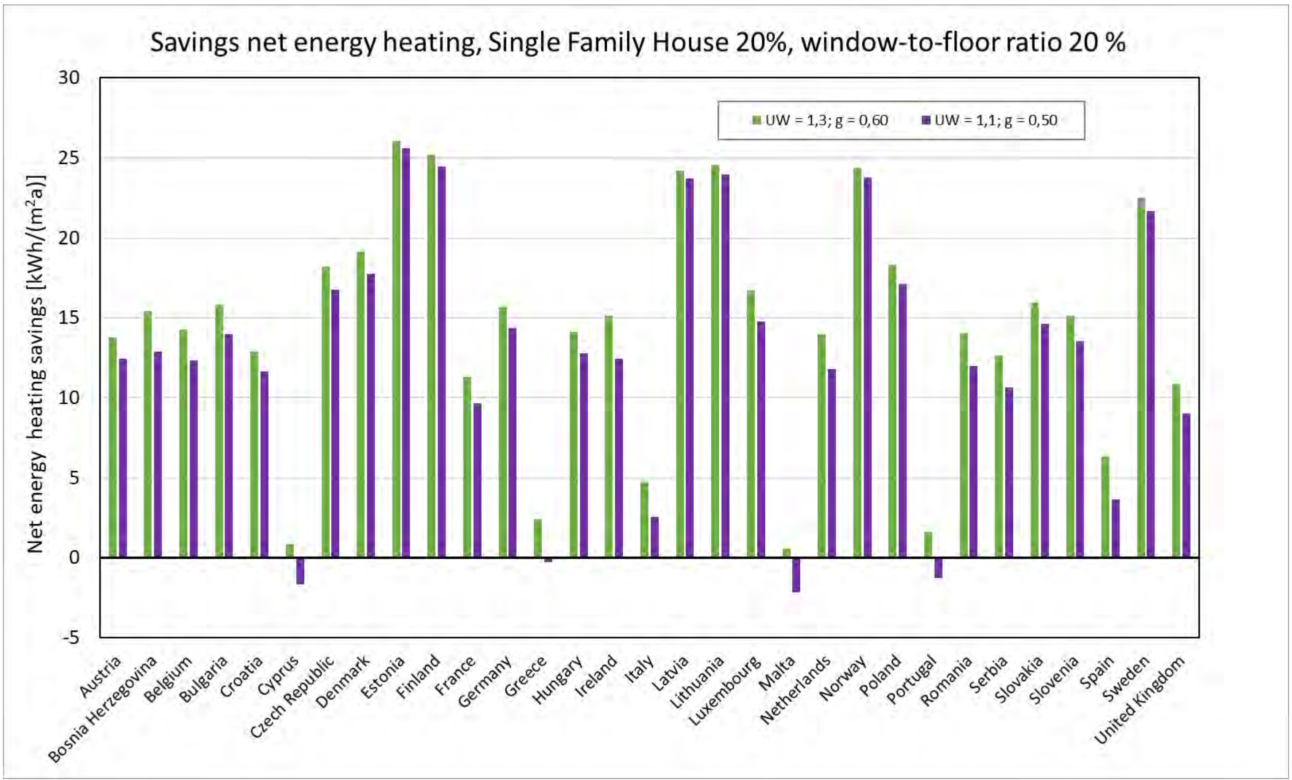

Figure 4-2: Saving potential of net energy for a single-family house, window-to-floor ratio of 20 % for two different renovation scenarios: 1. U_w = 1,3 W/(m²K) and g = 0,60 (green bars) and 2. U_w = 1,1 W/(m²K) and g = 0,50 (purple bars)

As already mentioned before, the saving potentials strongly depend on what climate shall be assessed. While there are big saving potentials in northern and central regions of Europe, southern regions show that even higher energy demands can result when new windows are compared with the base case window. But it has to be taken into account, that for the calculated southern regions the level of heating energy demand is very low in general (see Figure 4-1) and window replacement in these regions will not necessarily be driven by the goal to save heating energy (other than in the mountain regions of these countries) but by key indicators for renovation like getting more daylight, avoiding overheating, updating design (incl. visual expression of the building, safety and accessibility in use, protection against noise, burglar resistance etc.) or to update warn out windows with more modern ones where shading products can be further included.

What can also be seen when looking at the savings for the two different replacement windows in Figure 4-2 is, that there are bigger saving potentials in all countries due to a window replacement for the green bars with U_w = 1,3 W/(m²K) and g = 0,60 compared to a window replacement shown for the purple bars with U_w = 1,1 W/(m²K) and g = 0,50. This is of high importance because of between these two window types there is a technology switch from two-layer to three-layer windows, where the improvement of the U-value from 1,3 to 1,1 W/(m²K) and the corresponding savings in transmission losses are weighing less than the reduction of solar gains due to reduction in the g-value from 0,6 to 0,5. And this is exactly the point where regulations and requirements focussing only on transmission losses fail regarding the goal to lead to energy savings.

Savings due to window replacements have been carried out in this study for

- renovation windows (U-value of windows varied between 0,80 and 1,4 W/(m²K) in steps of 0,10 and for each with the g-values 0.40, 0.50 and 0.60) for
- base case 1 and base case 2 and
- for the single-family-house (SFH) and multi-family-house (MFH) with
- window-to-floor-ratios of 10 %, 20 % and 30 %.

Thus, for each country and each case it is possible to create figures like Figure 4-3 where as an example for Poland the net-energy savings for a single-family-house with a window-to floor ratios 20 % and a thermal-insulation-level corresponding to base case1 is given for the different U_W-values of the renovation options and their three different g-values (blue bars for g = 0.40, red bars for g = 0.50 and green bars for g = 0.60). The corresponding results for a multi-family house as well as savings for base case 2 for the single-family house and the multi-family house are given in Appendix C, where the figures are also given for window-to-floor ratios of 10 % and 30 %.

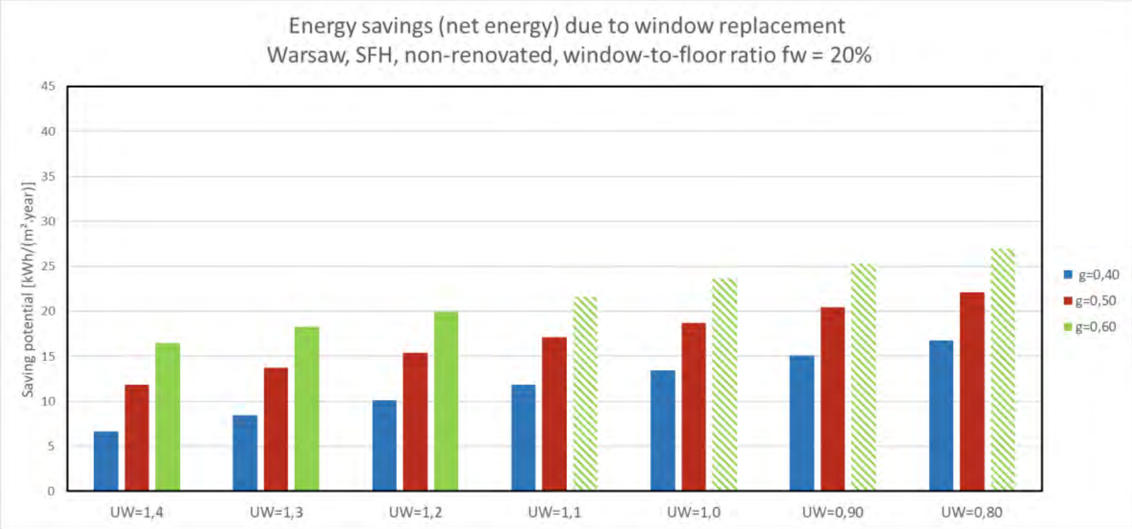

Figure 4-3: Net-energy savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

From out of the results shown in Figure 4-3 and in Appendix C (for further window-to-floor ratios, multi-family-house and assessments for base case 2) the following general interpretations are derived:

- the savings in energy demand depend on the U-value and on the g-value of a window
- looking only at the U-value cannot identify the highest saving potentials because of the influence of the g-value is higher (in the frame of calculated range of parameters)
- the higher the window-to-floor-ratios the bigger the saving potential are
- when looking at an individual U-value, the savings can be more than double for a g-value of 0.60 compared to a g-value of 0.40 (for U_W = 1.4 W/(m²K) in Figure 4-3: savings for g = 0.60 reach 16.5 kWh/(m²a) while for g = 0.40 savings reach only 6.6 kWh/(m²a))

On the basis of the methodology described above for the net energy savings, the final energy savings can be calculated as described in the following chapter 4.1.2.

4.1.2 Final energy

Final-energy is calculated by multiplying the net-energy with the final-energy-expenditure factor. In the frame of this study average factors for each country are used as described in chapter 3.6. If information about an individual heating system of the building is available, individual calculations on the basis of the net energy results can be assessed. For the situation single-family-house with a window-to-floor ratio of 20 % and base case 1 the final energy results are shown in Figure 4-4.

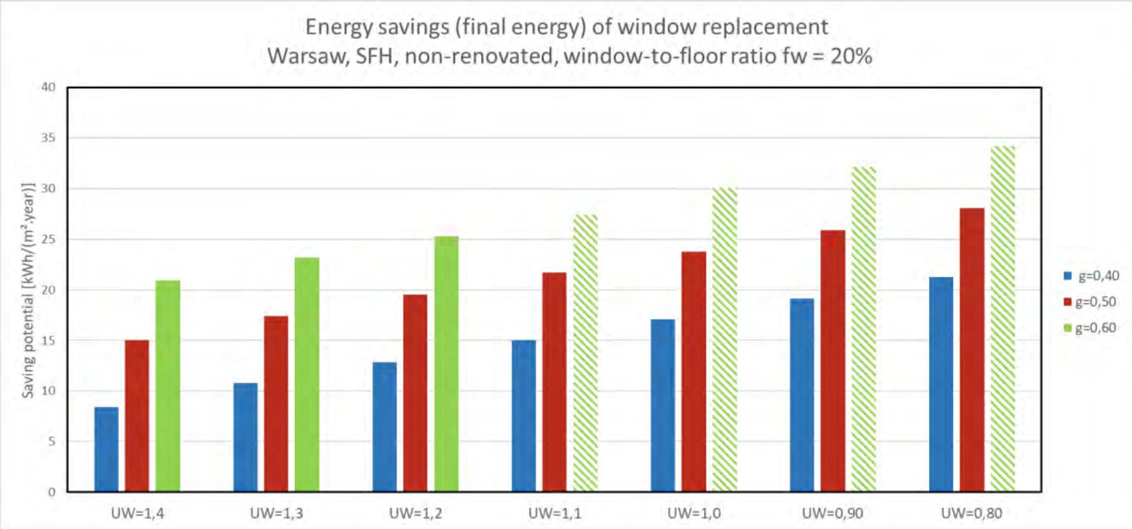

Figure 4-4: Final energy savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

4.1.1 CO_2 emissions

CO_2-emissions are calculated by multiplying the final-energy with the CO_2-emission factor. As described in chapter 3.6 the results in this report are given for individual CO_2-emissions per country where the information is available. In case of no national values are available, the emissions of representants for the climate regions north, central and south are used for the calculations. Like in case of assessing the finale energy, if detailed information about individual buildings and their heat supply is available, individual assessments are possible on the basis of the net energy results multiplied with individual energy expenditure factors and CO_2-emission values corresponding to the individual heat supply.

For Poland, the average savings in CO_2-emissions are given in the following Figure 4-5.

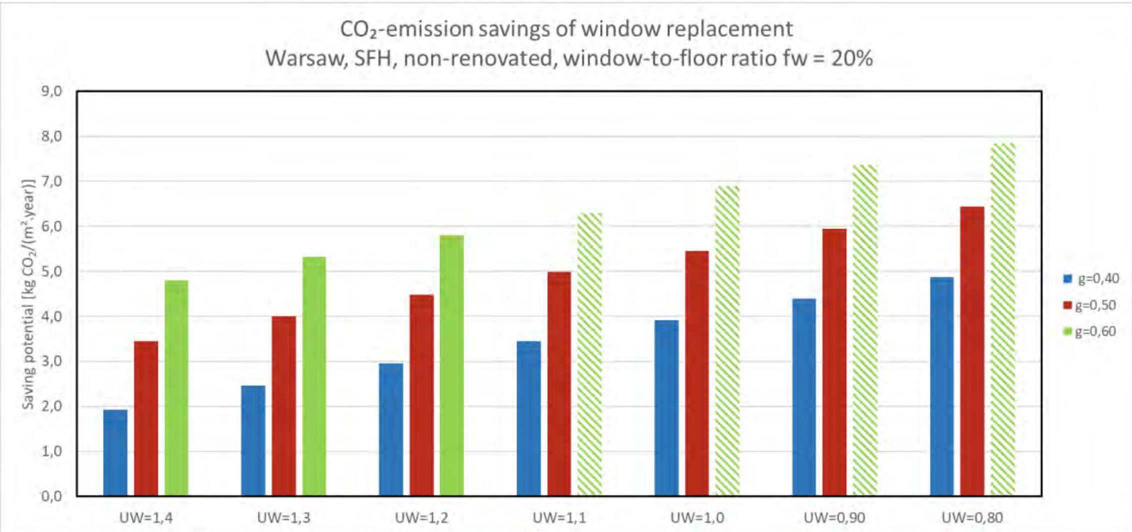

Figure 4-5: CO_2-emission savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

4.1.2 Savings in money due to final energy savings

Once the potential in final energy savings are known it is possible to assess the corresponding monetary savings. On the basis of average heating costs in Poland of 0.05 €/kWh, as evaluated in the frame of LOT 32 [5], monetary savings for the boundaries corresponding to Figure 4-4 result as shown in Figure 4-6.

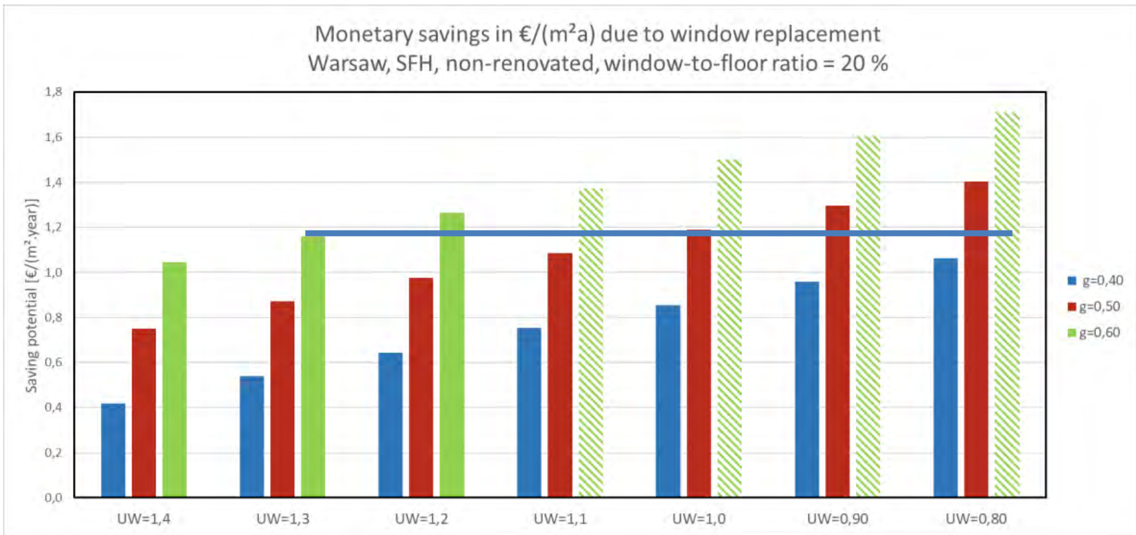

Figure 4-6: Monetary savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

To explain what is shown in Figure 4-6 with specific savings in € per m², for a single-family house with 130 m² renovated with a window with U_W = 1,3 W/(m²K) and g = 0,60 monetary savings due to window replacement (specific savings of 1.2 €/(m²a)) of 156 € per year are reached. A renovation window with U_W = 1,1 W/(m²K) and g = 0,50 (specific savings of 1.1 €/(m²a)) leads to savings of 143 € per year. In this special case the choice of the window U_W = 1,3 W/(m²K) and g = 0,60 would be the better choice. Looking only at the U-value the planner would expect a better energy performance by using the window with U_W = 1,1 W/(m²K). This underlines again how important it is to look also to the window properties that describe the solar gains which have a significant impact on the heating demand reduction.

4.2 Savings on a national level – example Poland

The results on a building level as documented in chapter 4.1 show a very significant impact of window replacement on the energy demand for different boundaries where different internal gains due to different usages (SFH and MFH), different window-to-floor ratios and two different base cases are assessed. In additions to such assessments on a building level it is of high interest, how window replacement can reduce the overall national energy demand for heating. To be able to derive such numbers, it is necessary to extrapolate the results of the building assessment with regards to country specific information about the individual national building stocks. For this report the information about the national building stock, its distribution over different construction period was taken out of the European Buildings database [3], which also distinguishes between single-family stock and multi-family stock. Information about the total usable floor area is take out of the final and consolidated report of LOT 32 - Task 7 [10], table 185. The methodology of extrapolation is described in chapter 3.3.4.

Due to in the aforementioned databases no specific information regarding the window-to-floor area is given, the following figures and results assume an average window-to-floor area of 20 % for all national extrapolations. Due to Poland was taken as example for the assessments on a building level, Poland is also taken as example for the main part of this report. Results for all EU 28 countries are given in Appendix D.

For final-energy and CO_2-assessment is hereby taken into account as described in chapter 3.6.

4.2.1 Final energy and monetary savings

The saving results on a national level for each country is calculated with national floor- and window-area as described in chapters 3.3.4 and 3.7.

As an example, Figure 4-7 shows the final-energy-savings in Poland for a window-to-floor ratio of 20 % (Appendix D provides results all EU 28 countries).

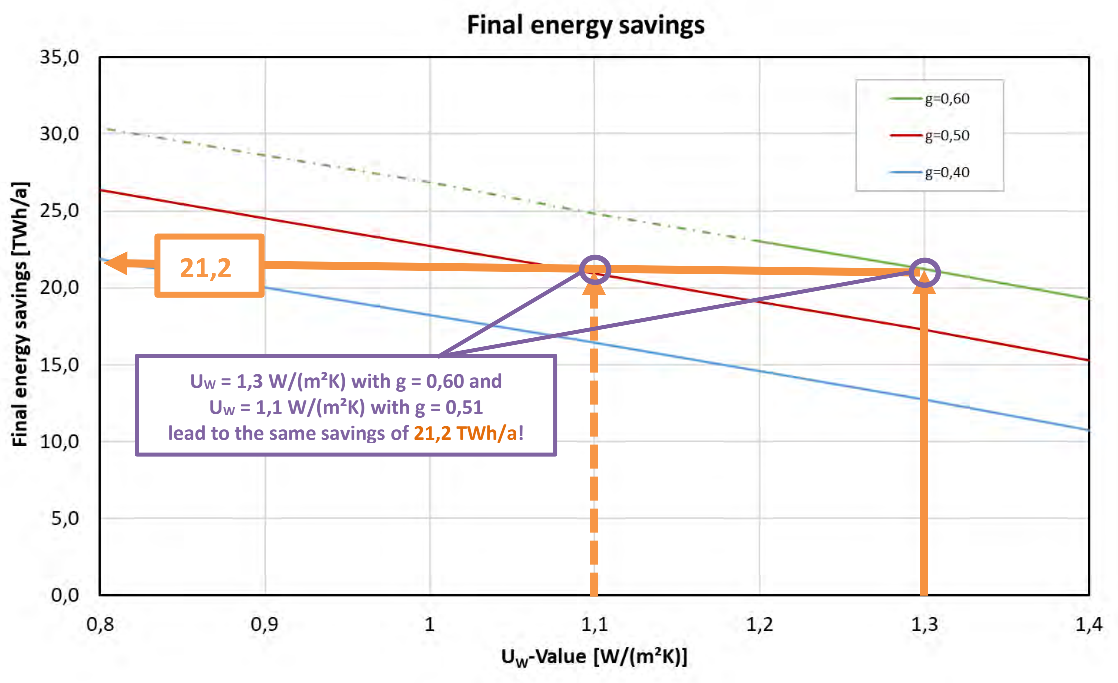

Figure 4-7: Final-energy-savings in Poland for a window-to-floor-ratio of 20 %

The graphs in Figure 4-7 describe the overall national saving potential in Poland when the relevant part of the whole national building stock which belongs to the defined periods for the two bases cases (see Table 3-3) is renovated. **Hereby all combinations for U- and g-values on a horizontal line are energetically equivalent.** To explain this and as example, how Figure 4-7 and the following graphs can be used to derive or compare saving potentials, the renovation scenario for a window with U_W = 1,3 W/(m²K) and g = 0,60 is marked with orange arrows in Figure 4-7. Another orange arrow with dashed orange line is drawn for the renovation scenario with U_W = 1,1 W/(m²K) and g = 0,51. Renovating the whole building stock would for both cases mean 21,2 TWh final energy savings per year for heating due to replacing the old windows.

Assuming average heating costs of 0,05 €/kWh, this would save 1.060 Mio. € (1,06 billion) compared with the heating costs for the base case window with U_W = 2,8 W/(m²K) and g = 0,76. Any other combination for a U_W-value and a g-value which is on the horizontal orange line is energetically equivalent and leads to the same savings of 21,2 TWh/a. To make this number better understandable: In the year 2015 the overall final energy consumption in Poland reached 62,3 million tonnes of oil equivalent [14] which corresponds to 724 TWh. Regarding this overall consumption, the saving results due to window replacement from the examples above with 21,2 TWh per year reach almost 3 %.

4.2.2 CO_2 emissions

For calculating the CO_2-savings from the final energy specific national CO_2-emissions are used as described in chapter 3.6 are used. As an example, Figure 4-8 shows the CO_2-savings of Poland for a window-to-floor-ratio of 20 %.

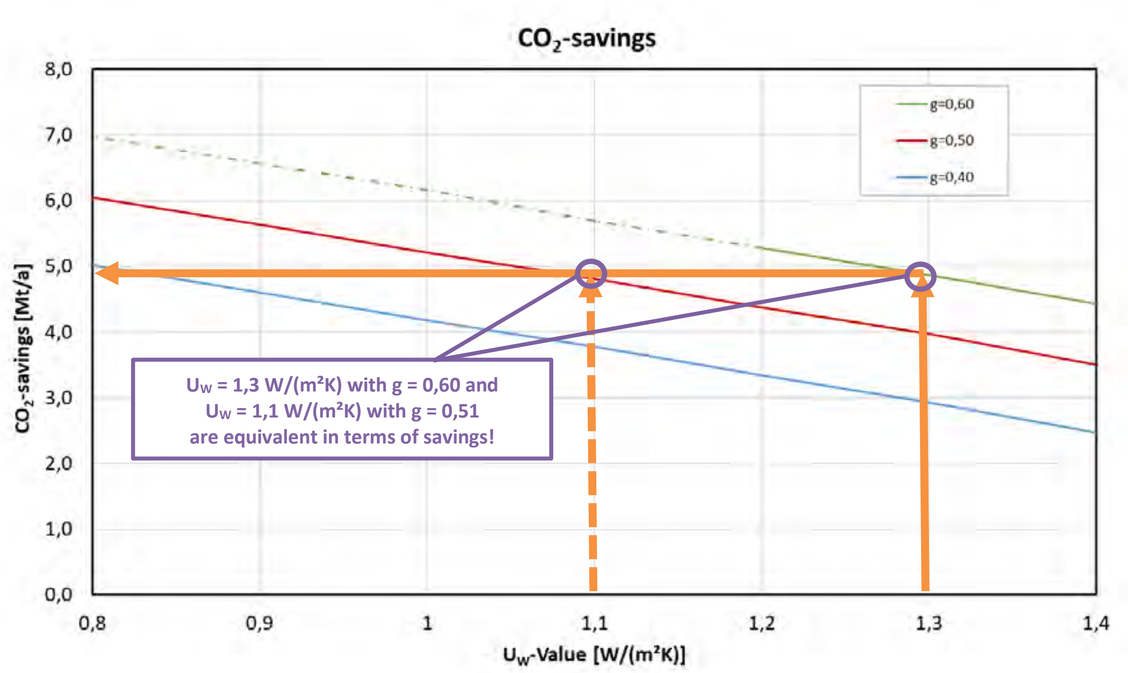

Figure 4-8: CO_2-savings in Poland for a window-to-floor-ratio of 20%

The way, Figure 4-8 has to be read and interpreted is the same as described above for the final energy savings. For a renovation window with U_W = 1,3 W/(m²K) and g = 0,60 CO_2-savings of 5,9 Mt per year are possible. As already explained above, this saving potential corresponds to 3 % savings of the total national CO_2-emissions in Poland. With regards to around 38 Mio. inhabitants and yearly CO_2-emissions per capita of around 10 tonnes [15] the savings of the example above correspond to the total CO_2-emissions from 560.000 people.

In Appendix D provides results for all EU 28 countries.

4.3 Savings on European level

The results given in this chapter are derived by summation of all national saving potentials of the 28 EU-countries as given in Appendix D. Hereby the summation of savings is only done by summing up the positive saving potentials (negative savings occur in some southern European countries for variants with low g-values).

4.3.1 Final energy and monetary savings

The result on an EU-28-level is shown in Figure 4-9. Additional results with savings separated for Northern, Central and Southern Europe are given in Appendix E, chapter E 1.

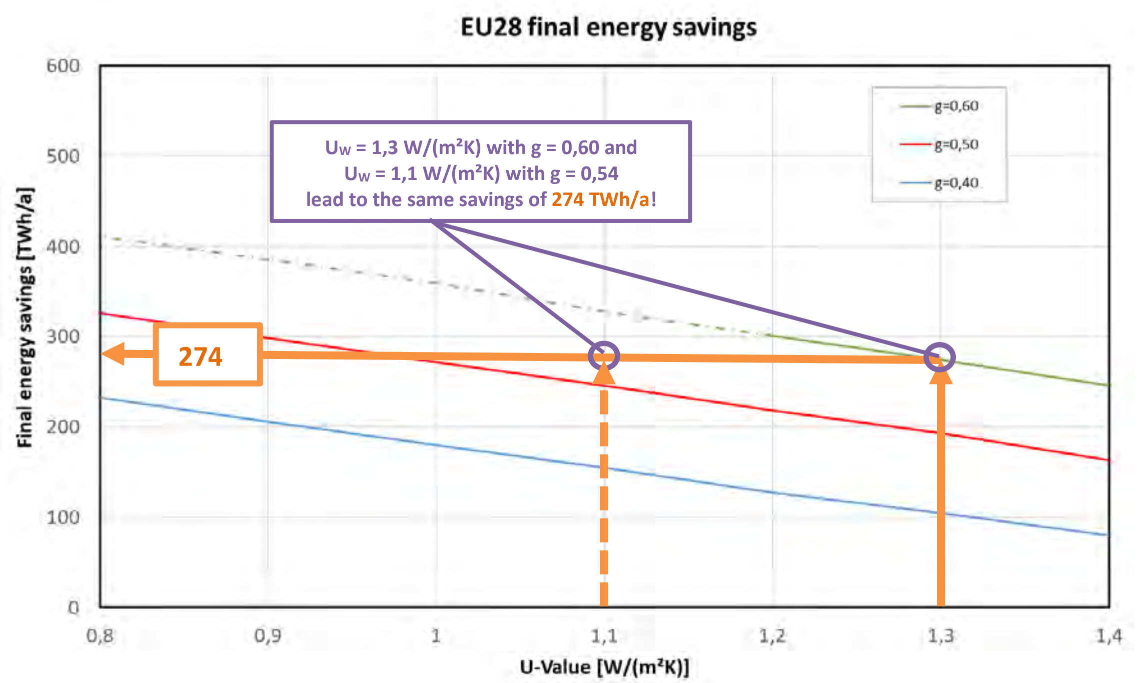

Figure 4-9: Final-energy-savings on a EU28-level

To make it clear, how important it is, to include the solar gains into the process to identify the windows with the highest saving potentials two different windows with the same U-values but different g-values are assessed in Figure 4-9 with orange arrows:

- Replacing the whole building stock window with windows that have a U-value of 1,3 W/(m²K) and a g-value of 0,60 would lead to final energy savings of 274 TWh per year. The same savings can be reached with a combination of U_W = 1,1 W/(m²K) and g = 0,54. Here the benefits of using an energy balance approach is shown very clearly.

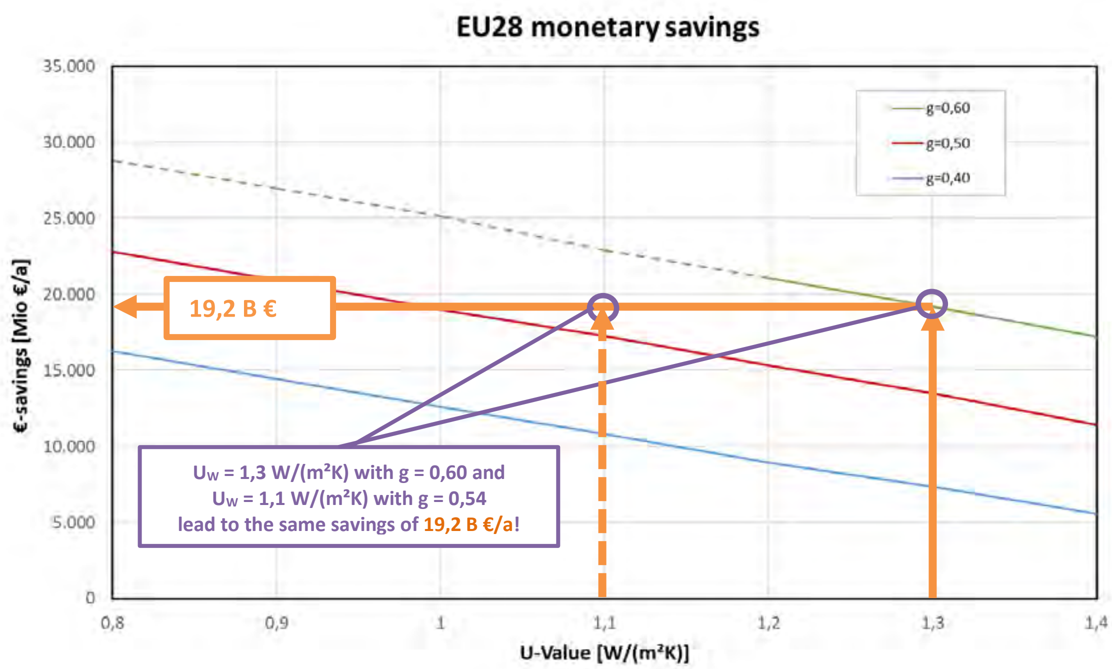

Figure 4-10: Monetary savings on a EU28-level due to energy savings for heating

Regarding the monetary savings the comparison of the two exemplary windows from above lead to corresponding results:

- the overall monetary savings with regards to specific national costs for heating energy reach 19,2 billion Euros per year when the whole building stocks windows are replaced by windows with U = 1,3 W/(m²K) and a g-value of 0,60.
- The same savings can be achieved with a combination of U = 1,1 W/(m²K) and a g-value of 0,54, but likely at a higher investment costs.

These results are elementary, because of only the additional recognition of the g-value in national requirements can ensure to identify solutions that lead to a more accurate picture of a window's contribution to a building. .

In addition to the monetary savings due to savings in energy, the inclusion of investments costs is of high importance for investors. Due to a very poor availability of data regarding current price levels for different windows and also because of strong deviations in the prices between the EU28 countries a full and comprehensive assessment regarding average cost-optimal solutions for renovation windows over all EU countries is neither senseful nor possible.

The general conclusion regarding finding the cost optimal solution is, that there are two important preconditions:

- the requirements for window replacement should include the usable solar gains, for example by using an **energy-balance approach**, to be able to compare different renovation options and to find the solution with the highest saving potential
- knowing the saving potentials for single renovation options, the additional **consideration of investment costs** for single renovation options leads to cost-optimal solutions for investors.

4.3.1 CO_2 emissions

The result on a EU28-level is shown in Figure 4-11.

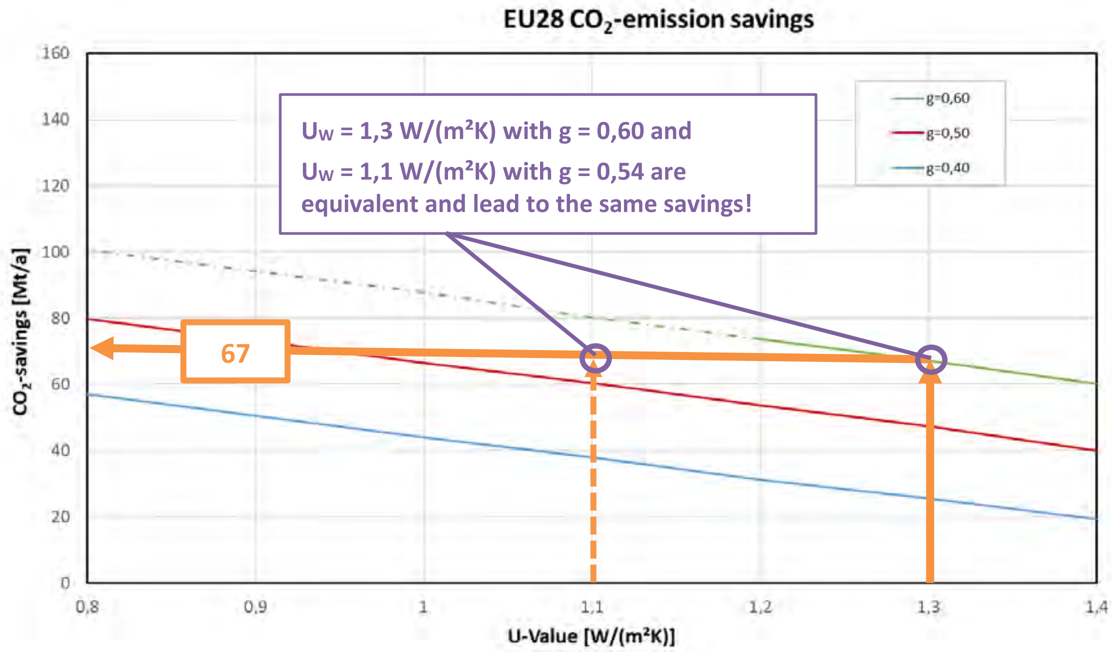

Figure 4-11: CO_2-savings on a EU28-level

With regards to the assessments above for the final energy savings and the monetary savings the results in Figure 4-11 show also a big difference when looking at the savings of CO_2-emissions.

As already explained in the beginning of the present chapter, all combinations for U_W- and g-values, that belong to a horizontal saving level, are energetically and with regards to the CO_2-emissions equivalent. For the CO_2-savings shown in Figure 4-11 this means for example that the savings for U_W = 1,3 W/(m²K) and g = 0,60, which are given with 67 Mt/a, can also be achieved by U_W = 1,1 W/(m²K) and g = 0,54. A window with an U_W-value of 1,1 W/(m²K) and a g value lower than 0,54 leads to less savings.

The final conclusion is, that there is a strong need to bring national regulations to requirements that include the significant impact of solar gains regarding the identification of best suitable renovation windows. Hereby the planning process automatically leads to the highest energy savings and CO_2-emission reductions.

4.3.2 Consequence on investment costs

As shown in the previous paragraphs, windows with various technical performances could lead to identical energy savings depending on the chosen combination of U_W-value and g-value. Using an energy balance approach to evaluate the performance of replacement windows would be a way to acknowledge this statement, and then to allow cost optimal choices for end-users. Nevertheless, in order to set appropriate requirements, cost analysis should be performed at national level to account for local market conditions.

- the requirements for window replacement should include the usable solar gains, for example by using an **energy-balance approach**, to be able to compare different renovation options and to find the solution with the highest saving potential
- knowing the saving potentials for single renovation options, the additional **consideration of investment costs** for single renovation options leads to cost-optimal solutions for investors.

5 Recommendations for further investigations to improve national requirements

The present study “Results of a pan-European study on energy savings due to window replacement” was carried out with the goal to assess the heating energy savings due to window replacement options in European countries. The results can either be used to quantify heating energy savings on a building level or on a national as well as on a EU28 level. For further utilization of the results of this study, the following bullet points describe recommendations for useful further investigations:

- ***Window replacement policies based on single U_w-value requirements should be replaced by energy-balance requirements to optimise and secure their efficiency***
  The outcome of the present study clearly shows, that U_W-values as single requirement is not sufficient to lead renovation to the highest saving potentials. Establishing requirements that take the usable solar gains into account, for example by using the energy-balance approach, are an elementary precondition for securing highest energy efficiency. Using energy-balance requirements for window replacement will hereby optimize investments.
- ***Energy-balance equations should be defined at national level to account for local climatic conditions***
  Climate conditions over the whole EU vary in a wide range, for example due to big differences in the height above sea level. The present study assesses national heating energy saving potentials as simplification on the basis of climate data for the capitals of each EU country. The results show that the differences in national saving potentials are significantly different even at that level. Therefore energy-balance equations should be developed at least at national level to account for local climatic conditions. Moreover, in case of there are significant differences in the height above sea level on a single national level, corresponding national requirements should be established where the variety in national climate is taken into account. As an example, the saving potentials in Italy are calculated by using climate data for Rome in the scope of the present study. As result, there are no significant saving potentials given due to the mediterranean climate in Rome. Hereby the results cannot stand for assessments in northern Italy where the climate conditions are more comparable to central European climate. Besides the improvement of national requirements, each planning and consulting process leads to better and more reliable results when the energetic performance is assessed by using climate that describes the local climate on site as good as possible.
- ***Energy-balance requirements should be based on cost-optimality***
  The energy-balance requirements should not only include an assessment of monetary savings due to savings in energy but also the investment costs for single renovation options. Due to the various price developments over the whole EU and even on national level, the inclusion of investment costs and the derived cost-optimal renovation option always depends on the input parameters for the economic calculation.
- ***For cooling dominated countries, policies should include expectable savings for cooling as they account for a significant part of building consumptions***
  While the intention of the present study is to assess heating energy savings for various renovation scenarios, corresponding investigations on cooling energy savings are very important for a full and comprehensive assessment of the energetic optimization of buildings. While the assessment of heating energy savings is mainly dependent on the U_W-value and the g-value of a window, the additional assessment of solar control glazing or solar shading systems is of high importance when cooling energy assessment shall be carried out. Additional assessments for the summertime is strongly recommended. Especially for cooling dominated countries – e.g. in southern Europe - energetic savings are strongly dominated by savings of cooling energy.

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[15] ____, *Total greenhouse gas emissions by countries, 1990 - 2015 (million tonnes of CO2 equivalents).* [Online] Verfügbar unter: http://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Total_greenhouse_gas_emissions_by_countries_(including_international_aviation_and_indirect_CO2,_excluding_LULUCF),_1990_-_2015_(million_tonnes_of_CO2_equivalents)_updated.png. Zuletzt geprüft am: 05.06.2018.

List of figures

List of tables

Appendix A Building Geometries

A 1 Single-family-house (SFH)

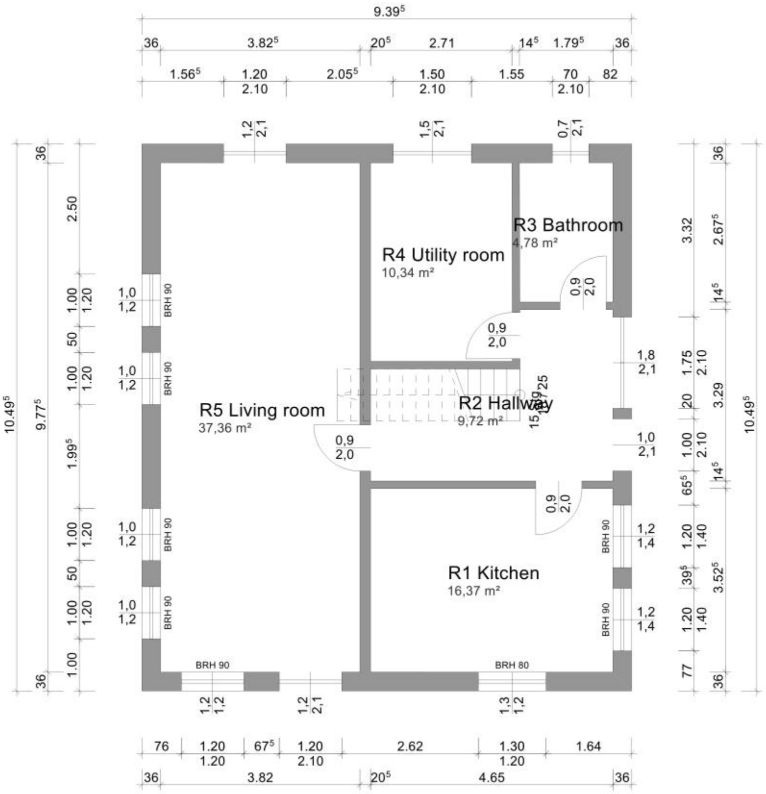


Figure A-1: SFH, floor plan ground floor

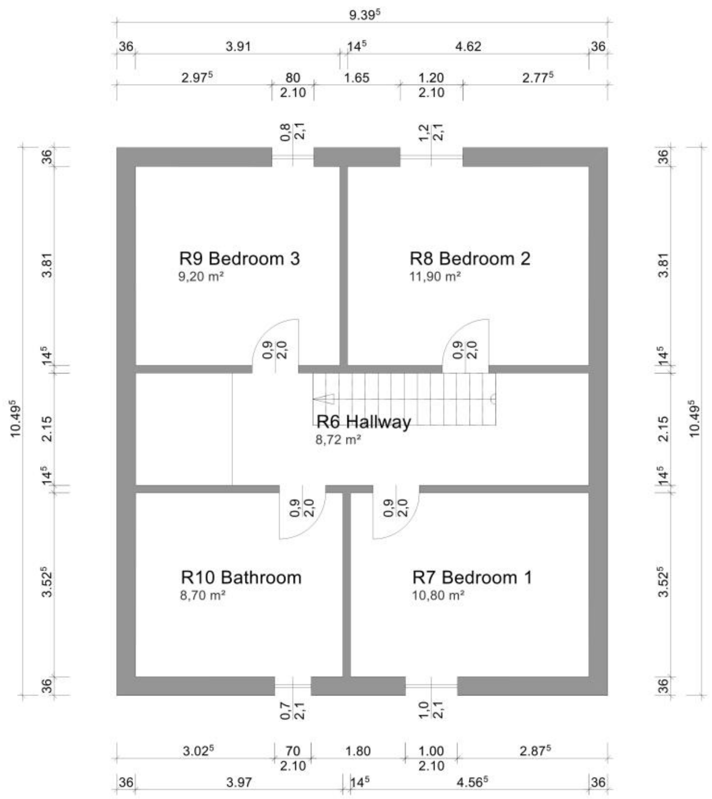


Figure A-2: SFH, floor plan 1st floor

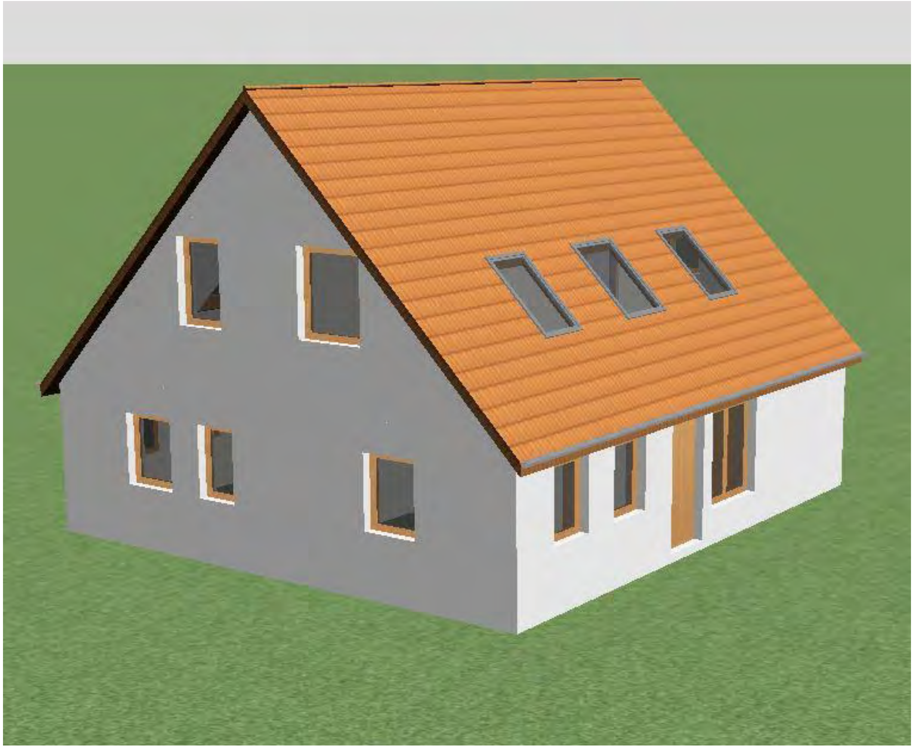


Figure A-3: SFH, view South/West

A 2 Unit in a multi-family-house (MFH)

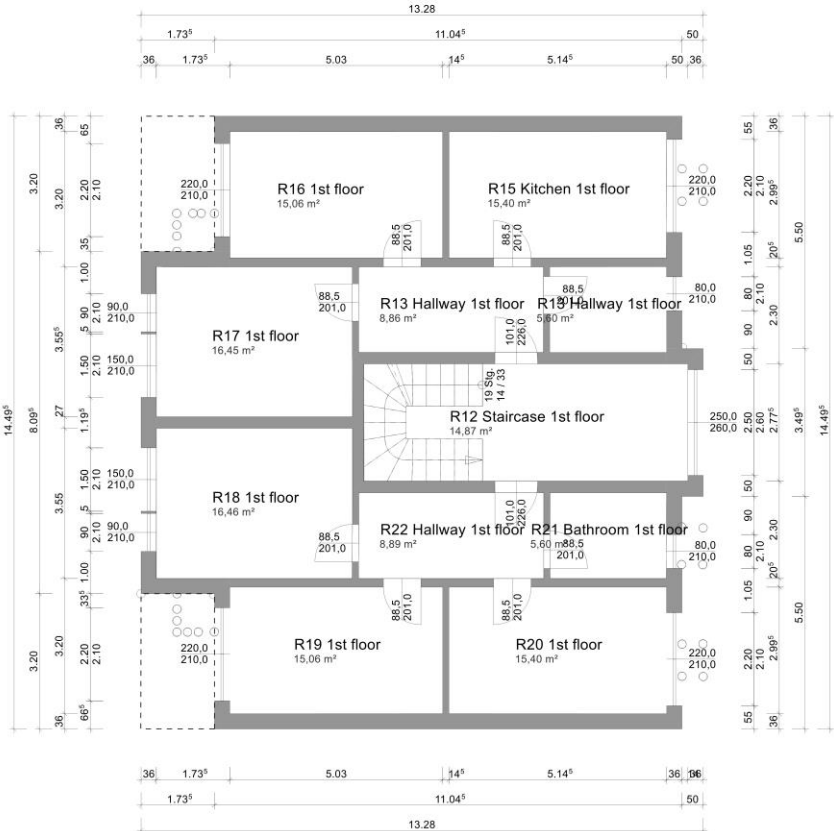


Figure A-4: MFH, floor plan

Figure A-5: MFH, South/East-view

Appendix B Country specific data

B 1 Information about the capitals of the EU member states as basis for the climate files

Table B-1: Country-specific meteorological data for EU Member States

No.	Init.	EU country	capital	latitude [°N]	longitude [°E]	altitude [MAMSL]	legal time [UTC]	time shift [h]
1	AT	Austria	Vienna	48,21	16,37	189	+1	0,09
2	BE	Belgium	Brussels	50,83	4,35	100	+1	-0,71
3	BG	Bulgaria	Sofia	42,67	23,30	573	+2	-0,45
4	HR	Croatia	Zagreb	45,80	15,97	146	+1	0,06
5	CY	Cyprus	Nicosia	35,15	33,35	5	+2	0,22
6	CZ	Czech Republic	Prague	50,09	14,42	206	+1	-0,04
7	DK	Denmark	Copenhagen	55,67	12,30	28	+1	-0,18
8	EE	Estonia	Tallinn	59,44	24,75	31	+2	-0,35
9	FI	Finland	Helsinki	60,17	24,94	25	+2	-0,34
10	FR	France	Paris	48,86	2,35	38	+1	-0,84
11	DE	Germany	Berlin	52,52	13,39	43	+1	-0,11
12	GR	Greece	Athens	38,00	23,73	0	+2	-0,42
13	HU	Hungary	Budapest	47,50	19,04	115	+1	0,27
14	IE	Ireland	Dublin	53,33	-6,25	5	+0	-0,42
15	IT	Italy	Rome	41,89	12,48	50	+1	-0,17
16	LV	Latvia	Riga	56,95	24,11	14	+2	-0,39
17	LT	Lithuania	Vilnius	54,68	25,29	98	+2	-0,31
18	LU	Luxembourg	Luxembourg	49,62	6,22	380	+1	-0,59
19	MT	Malta	Valletta	35,90	14,50	18	+1	-0,03
20	NL	Netherlands	Amsterdam	52,35	4,90	0	+1	-0,67
21	PL	Poland	Warsaw	52,23	21,01	127	+1	0,40
22	PT	Portugal	Lisbon	38,71	-9,14	18	+0	-0,61
23	RO	Romania	Bucharest	44,44	26,10	83	+2	-0,26
24	SK	Slovakia	Bratislava	48,15	17,11	148	+1	0,14
25	SI	Slovenia	Ljubljana	46,05	14,51	301	+1	-0,03
26	ES	Spain	Madrid	40,42	-3,70	662	+1	-1,25
27	SE	Sweden	Stockholm	59,33	18,06	21	+1	0,20
28	UK	United Kingdom	London	51,51	-0,13	18	+0	-0,01

B 2 Information about insulation quality for different construction periods

For each country the different intensities of colours in each line in in Figure B-1 describe how detailed or differentiated the country specific insulation qualities are described in the database.

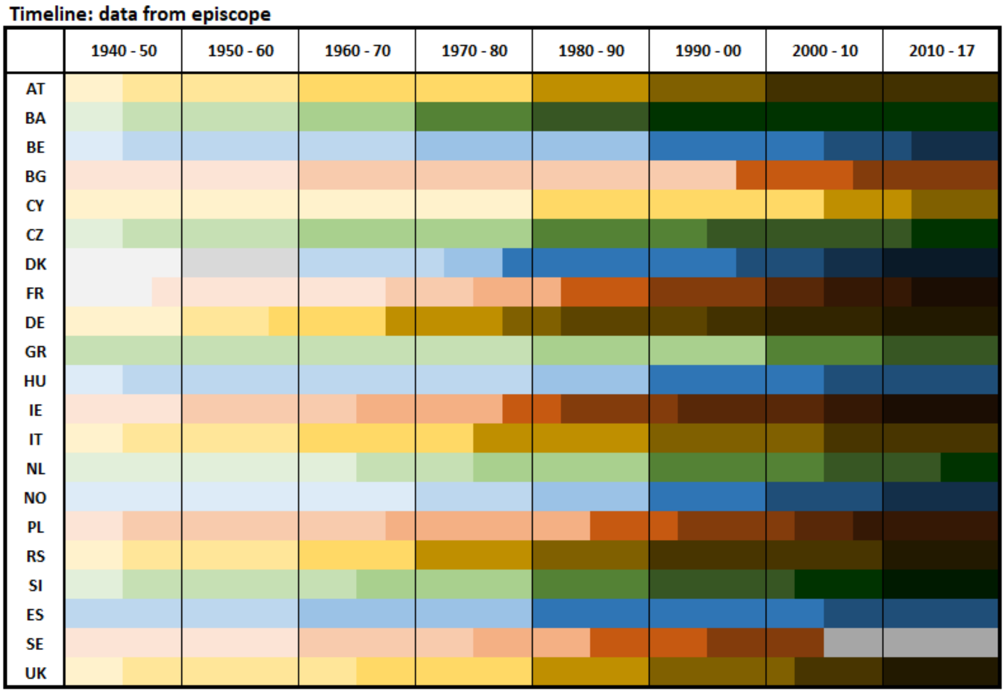


Figure B-1: Timeline: data from episcope

B 3 Overview U-values for different countries

B 3.1 Detailed information about country specific U-values in the period relevant for base case 1

Table B-2: Overview U-values [W/(m²K)] for buildings between 1960 and 1985 [8]

Country		roof	wall	floor	ceiling (cellar)	ceiling (attic)	door	window
Austria (1961-80)	SFH	0,90	1,30	0,65	-	-	2,.00	2,60
	MFH	0,58	1,80	1,10	-	-	-	1,50
	av. val.	0,80	1,40	0,80	-	0,70	-	2,70
Belgium (1971-90)	SFH	0,85 / 0,68	1,00 / 0,77	0,85 / 0,68	-	-	4,00	3,50
	MFH	0,85	1,00	0,68	-	-	4,00	4,30
	av. val.	1,32	1,56	0,95	-	-	-	3,53
Bulgaria (1960-98)	SFH	-	0,93	1,29	-	1,29	0,99	2,32
	MFH	0,59	0,93	1,29	-	-	5,85	2,63
	av. val.	-	-	-	-	-	-	-
Cyprus (... 1980)	SFH	3,42	1,39	1,97	-	-	5,85	6,10
	MFH	3,42	1,39	-	1,56	-	5,85	6,10
	av. val.	-	-	-	-	-	-	-
Czech Rep. (1961-80)	SFH	0,85	1,43	1,13	0,84	-	4,70	2,80
	MFH	0,85	1,08	1,03	-	-	6,50	2,80
	av. val.	0,85	0,93-1,47	1,28	-	1,60	2,9 - 6,5	1,3 - 2,7
Denmark (1973-78)	SFH	0,30	0,30	0,20	-	-	-	2,70
	MFH	0,19	0,49 / 0,60	0,46 / 0,19	-	-	-	2,80
	av. val.	-	0,30	0,30	-	0,54	-	2,70
France (1968-74)	SFH	1,35	2,80	1,43	-	-	-	2,60
	MFH	0,76	0,78	1,43	-	-	3,10	5,60
	av. val.	-	-	-	-	-	-	-
Germany (1969-78)	SFH	0,50	1,00	0,77 / 1,00	-	-	3,00	2,80
	MFH	-	1,00	0,77	-	0,51	4,00	3,00
	av. val.	0,77	1,15	1,05	-	-	-	2,64
Greece (... 1980)	SFH	3,05	0,95 / 3,40	3,10	1,25	-	-	3,10 / 4,70
	MFH	3,05	2,20 / 3,40	3,10	-	-	-	4,70
	av. val.	3,10	3,40	2,00	-	-	-	3,10
Hungary (1945-79)	SFH	0,94	1,35 / 1,78	0,98	-	-	3,50	3,50
	MFH	-	1,37	0,70	-	0,84	3,00	2,50
	av. val.	-	-	-	-	-	-	-
Ireland (1967-77)	SFH	0,68	1,78	1,38	-	-	-	5,70
	MFH	-	-	-	-	-	-	-
	av. val.	0,40 - 2,3	0,6 - 2,4	0,50 - 0,98	-	-	-	3,7 - 4,8

Country		roof	wall	floor	ceiling (cellar)	ceiling (attic)	door	window
Italy (1961-75)	SFH	2,20	1,26	2,00	-	-	3,00	4,90
	MFH	-	1,15	0,94	-	1,10	-	4,90
	av. val.	-	-	-	-	-	-	-
Netherlands (1965-74)	SFH	0,89	1,45	2,33	-	-	3,50	5,20 / 2,90
	MFH	0,89	1,45	2,33	-	-	3,50	5,20 / 2,90
	av. val.	-	-	-	-	-	-	-
Poland (1967-85)	SFH	0,50	1,03	1,60	-	-	4,00	2,60
	MFH	0,60	1,30	0,94	-	-	4,00	2,60
	av. val.	0,87	1,16 - 1,42	-	1,16	0,93	-	-
Slovenia (1971-80)	SFH	0,77	0,70	0,75	-	-	2,20	2,80
	MFH	-	1,80	0,75	-	1,17	-	2,80
	av. val.	0,6 - 0,9	0,83 - 1,68	0,7 - 0,9	0,52 - 1,04	0,69 - 1,16	-	-
Spain (1960-79)	SFH	4,17	1,33	0,85	-	-	-	4,59
	MFH	1,61	1,64	0,71	-	-	-	5,70
	av. val.	-	-	-	-	-	-	5,70
Sweden (1976-85)	SFH	0,15	0,21	0,27	-	-	2,80	2,01
	MFH	0,17	0,33 / 0,70	0,27	-	-	2,80	2,04
	av. val.	-	-	-	-	-	-	-
United Kingdom (1965-80)	SFH	1,50	1,60	0,59	-	-	1,80	4,80
	MFH	1,50	1,60	0,40	-	-	1,80	3,10
	av. val.	-	-	-	-	-	-	-

B 3.2 Detailed information about country specific U-values in the period relevant for base case 2

Table B-3: Overview U-values [W/(m²K)] for buildings between 1985 and 2005 [8]

Country		roof	wall	floor	ceiling (cellar)	ceiling (attic)	door	window
Austria (1991-00)	SFH	0,28	0,35 / 0,30	-	0,40	-	0,70	1,40
	MFH	0,36	0,35	-	0,36	-	-	1,40
	av. val.	0,30	0,40	0,50	-	0,30	-	1,80
Belgium (1991-05)	SFH	0,6 / 0,51	0,6 / 0,51	-	0,70 / 0,58	-	3,50	3,50
	MFH	0,45	0,60	-	0,58	-	-	3,50
	av. val.	0,69	0,81	0,76	-	-	-	2,53
Bulgaria (1999-08)	SFH	0,27	0,44	1,21	-	-	0,85	1,10
	MFH	0,27	0,43	1,29	-	-	0,85	1,10
	av. val.	0,30	0,50	0,50	-	-		1,80-2,60
Cyprus (1981-06)	SFH	3,42	1,39	-	1,97	-	5,85	6,10
	MFH	3,42	1,39	-	1,56	-	5,85	6,10
	av. val.	-	-	-	-	-	-	-
Czech Rep. (1981-94)	SFH	0,35	0,96	1,10	-	-	2,60	2,80
	MFH	0,35	0,87	1,10	-	-	6,50	2,80
	av. val.	0,35-0,46	0,73-0,78	0,60-1,10	-	0,60	2,00	1,10
Denmark (1979-98)	SFH	0,11	0,48	0,33	-	-	-	1,50
	MFH	0,19	0,34	0,19	-	-	-	2,70
	av. val.	-	0,48	0,11	-	0,33	-	1,50
France (1990-99)	SFH	0,22	0,36 / 0,32	0,42	-	-	2,50	2,60
	MFH	0,38 / 0,38	0,33 / 0,30	0,36 / 0,34	-	-	2,00	2,60
	av. val.	-	-	-	-	-	-	-
Germany (1984-94)	SFH	0,40	0,50	0,51	-	-	3,00	3,20
	MFH	0,36	0,60	0,51	-	-	4,00	3,00
	av. val.	0,40	0,64	0,71	-	-	-	2,37
Greece (1981-00)	SFH	3,05	0,85 / 3,40	-	2,75	-	-	6,10
	MFH	3,05	2,20 / 3,40	2,75	1,25	-	-	6,10
	av. val.	3,10	0,85	-	2,75	-	-	6,10
Hungary (1990-05)	SFH	0,25	0,49	-	0,37	0,32	2,50	2,00
	MFH	0,36	0,49	-	0,37	0,32	2,50	2,00
	av. val.	-	-	-	-	-	-	-
Ireland (1994-04)	SFH	0,26	0,55	0,86	-	-	3,00	2,80
	MFH	0,35	0,55	0,86	-	-	-	2,80
	av. val.	0,26-0,35	0,55	0,35-0,48	-	-	-	2,80

Country		roof	wall	floor	ceiling (cellar)	ceiling (attic)	door	window
Italy (1991-05)	**SFH**	-	0,59	0,63	-	0,57	1,70	2,80
	MFH	-	0,59 / 0,51	0,77 / 0,63	-	0,57	-	2,20
	av. val.	-	-	-	-	-	-	-
Netherlands (1992-05)	**SFH**	0,36	0,36	0,36	-	-	3,50	2,90 / 1,80
	MFH	0,36	0,36	0,36	-	-	3,50	2,90 / 1,80
	av. val.	-	-	-	-	-	-	-
Poland (1993-02)	**SFH**	0,40	0,40	1,00	-	-	2,50	1,60
	MFH	0,50	0,19	0,65	-	-	2,50	1,60
	av. val.	0,30	0,30-0,50	-	0,60	0,30	2,60	1,70-1,80
Slovenia (1981-01)	**SFH**	0,29	0,52	0,54	-	-	-	1,60
	MFH	0,77	0,62	0,65	-	-	2,20	1,40
	av. val.	0,50	0,60	0,60	0,50	0,50	-	-
Spain (1980-06)	**SFH**	0,61	0,60	0,85	-	-	-	3,09
	MFH	0,56	0,60	1,39	-	-	-	-
	av. val.	-	-	-	-	-	-	-
Sweden (1986-95)	**SFH**	0,12	0,17	0,24	-	-	2,80	1,94
	MFH	0,15	0,22 / 0,70	0,24	-	-	2,80	1,80
	av. val.	-	-	-	-	-	-	-
United Kingdom (1991-03)	**SFH**	0,35	1,60	0,40	-	-	1,80	3,10
	MFH	0,35	1,60	0,40	-	-	1,80	3,10
	av. val.	-	-	-	-	-	-	-

B 4 Data for assessments of final and primary energy and for CO2-emission calculations

Table B-4: Summary of country specific final and primary energy-factors and CO_2-emission factors

No.	Country		Climate region	CO_2 emission factor [kg/kWh]	final energy factor				primary energy factor			
					SFH base 1	SFH base 2	MFH base 1	MFH base 2	SFH base 1	SFH base 2	MFH base 1	MFH base 2
1	Austria	AT	Central	0,151	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
2	Belgium	BE	Central	0,229	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
3	Bulgaria	BG	South	0,230	1,98	1,43	1,22	1,20	0,96	0,98	1,26	1,15
4	Croatia	HR	Central	0,230	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
5	Cyprus	CY	South	0,247	1,98	1,43	1,22	1,20	0,96	0,98	1,26	1,15
6	Czech Republic	CZ	Central	0,315	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
7	Denmark	DK	Central	0,230	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
8	Estonia	EE	North	0,230	0,97	0,99	1,04	1,01	2,03	2,14	1,95	2,07
9	Finland	FI	North	0,230	0,97	0,99	1,04	1,01	2,03	2,14	1,95	2,07
10	France	FR	Central	0,333	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
11	**Germany**	**DE**	**Central**	**0,228**	**1,27**	**1,24**	**1,16**	**1,14**	**0,98**	**1,02**	**1,07**	**1,12**
12	**Greece**	**EL**	**South**	**0,160**	**1,98**	**1,43**	**1,22**	**1,20**	**0,96**	**0,98**	**1,26**	**1,15**
13	Hungary	HU	Central	0,307	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
14	Ireland	IE	Central	0,263	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
15	Italy	IT	South	0,241	1,98	1,43	1,22	1,20	0,96	0,98	1,26	1,15
16	Latvia	LV	North	0,230	0,97	0,99	1,04	1,01	2,03	2,14	1,95	2,07
17	Lithuania	LT	North	0,230	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
18	Luxembourg	LU	Central	0,230	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
19	Malta	MT	South	0,230	0,97	0,99	1,04	1,01	2,03	2,14	1,95	2,07
20	Netherlands	NL	Central	0,213	0,99	1,10	1,02	1,05	1,20	1,09	1,16	1,15
	Norway		**North**	**0,095**	**0,97**	**0,99**	**1,04**	**1,01**	**2,03**	**2,14**	**1,95**	**2,07**
21	Poland	PL	Central	0,230	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
22	Portugal	PT	South	0,230	1,98	1,43	1,22	1,20	0,96	0,98	1,26	1,15
23	Romania	RO	Central	0,259	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
24	Slovakia	SK	Central	0,230	1,27	1,24	1,16	1,14	0,98	1,02	1,07	1,12
25	Slovenia	SI	Central	0,180	1,15	0,90	1,08	0,87	0,81	0,82	0,89	0,86
26	Spain	ES	South	0,201	1,98	1,43	1,22	1,20	0,96	0,98	1,26	1,15
27	Sweden	SE	North	0,230	0,97	0,99	1,04	1,01	2,03	2,14	1,95	2,07
28	United Kingdom	UK	Central	0,250	1,43	1,21	1,37	1,11	1,10	1,11	1,27	1,55

Appendix C Further results on a building level for showing the differences between SFH/MFH and between base case 1 and base case 2 (shown for Poland, Warsaw)

C 1 Base case 1, SFH

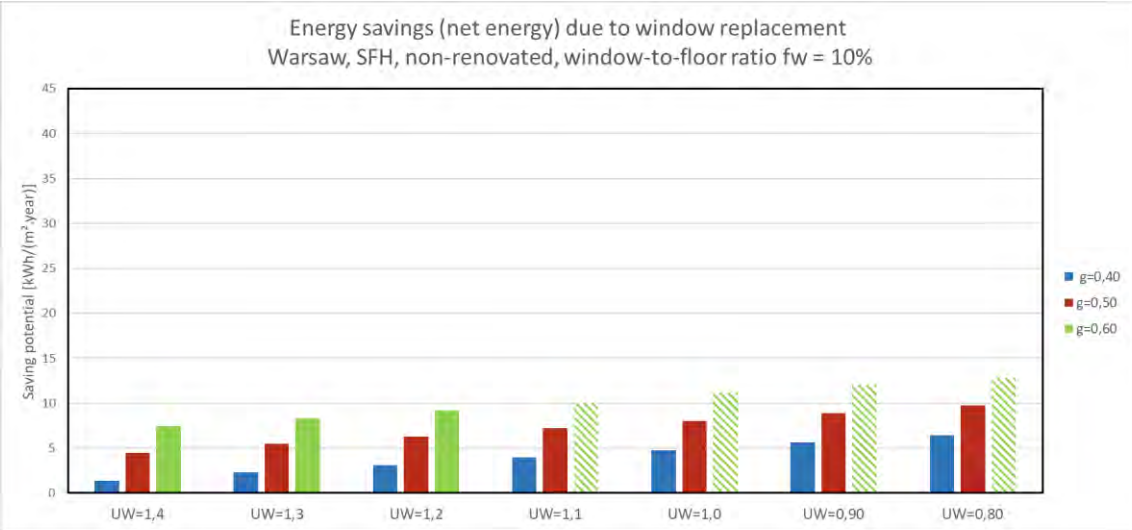


Figure C-1: Net-energy savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 10 %

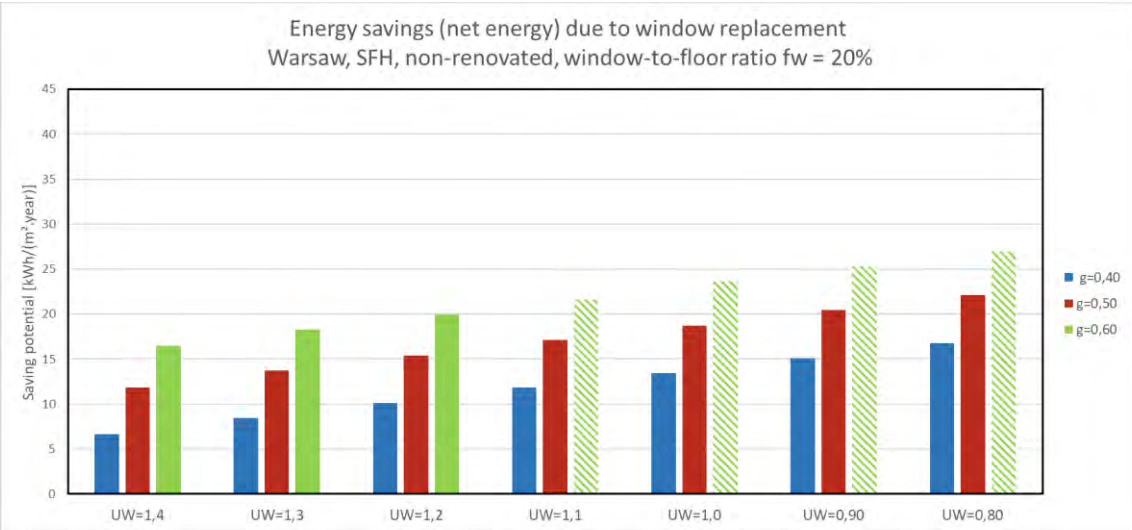


Figure C-2: Net-energy savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

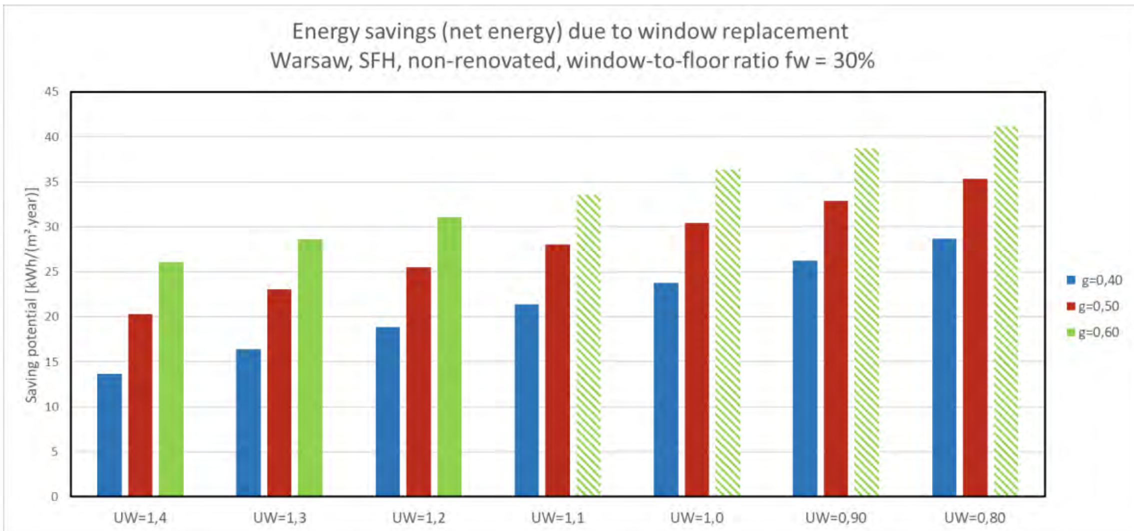


Figure C-3: Net-energy savings for a single-family-house in Warsaw, base case 1, window-to-floor ratio of 30 %

C 1 Base case 1, MFH

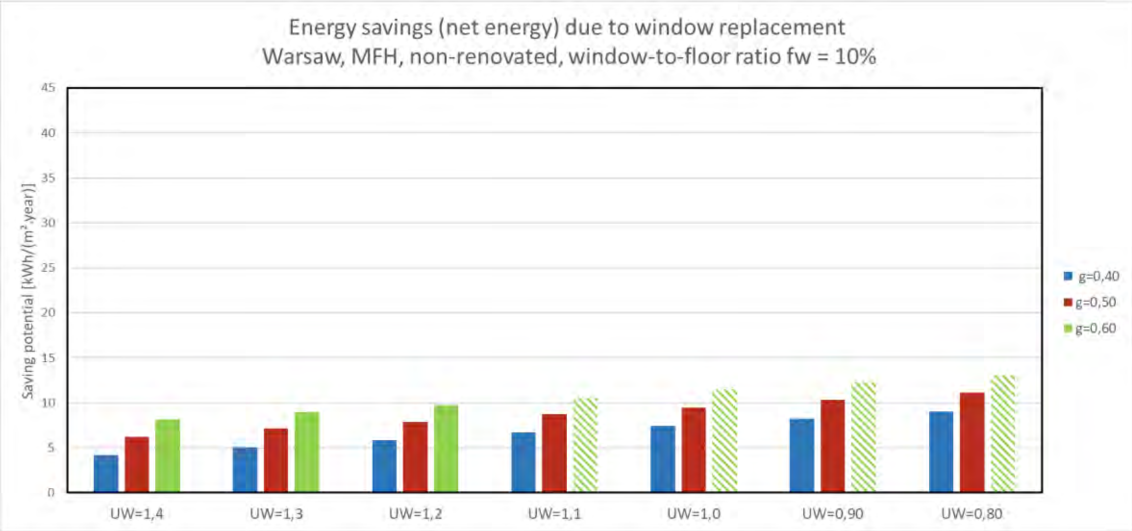


Figure C-4: Net-energy savings for a multi-family-house in Warsaw, base case 1, window-to-floor ratio of 10 %

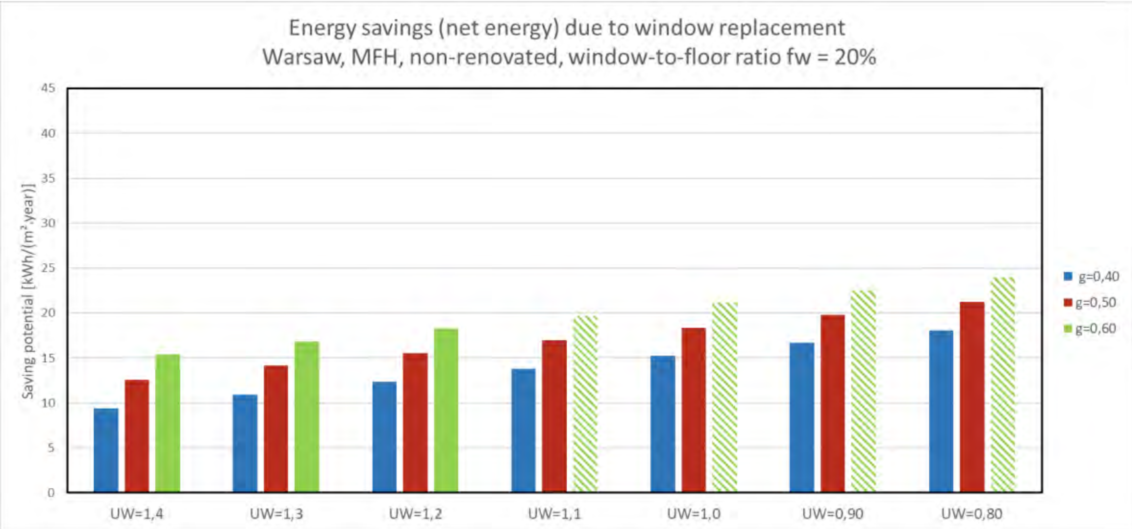


Figure C-5: Net-energy savings for a multi -family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

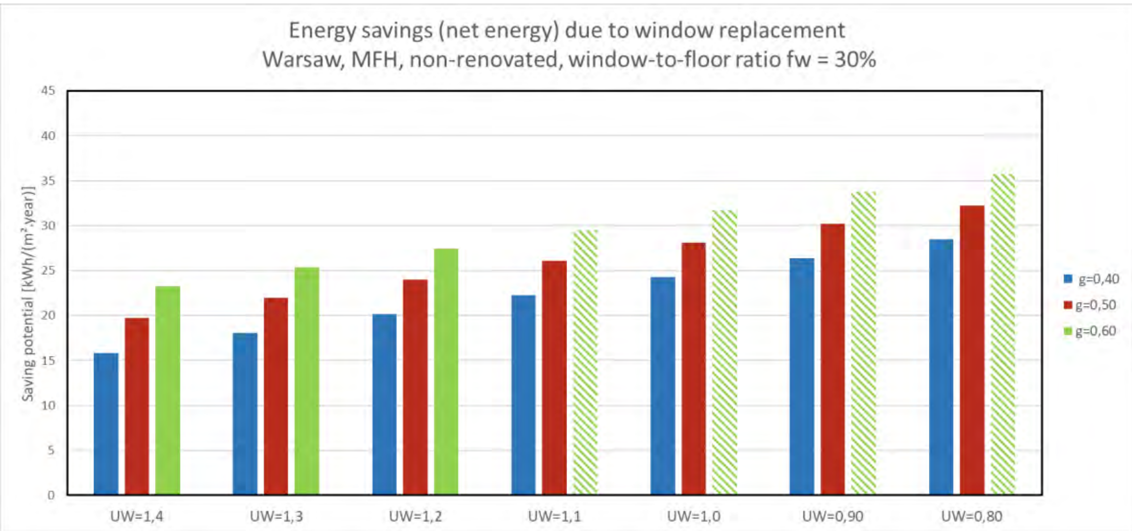


Figure C-6: Net-energy savings for a multi -family-house in Warsaw, base case 1, window-to-floor ratio of 30 %

C 1 Base case 2, SFH

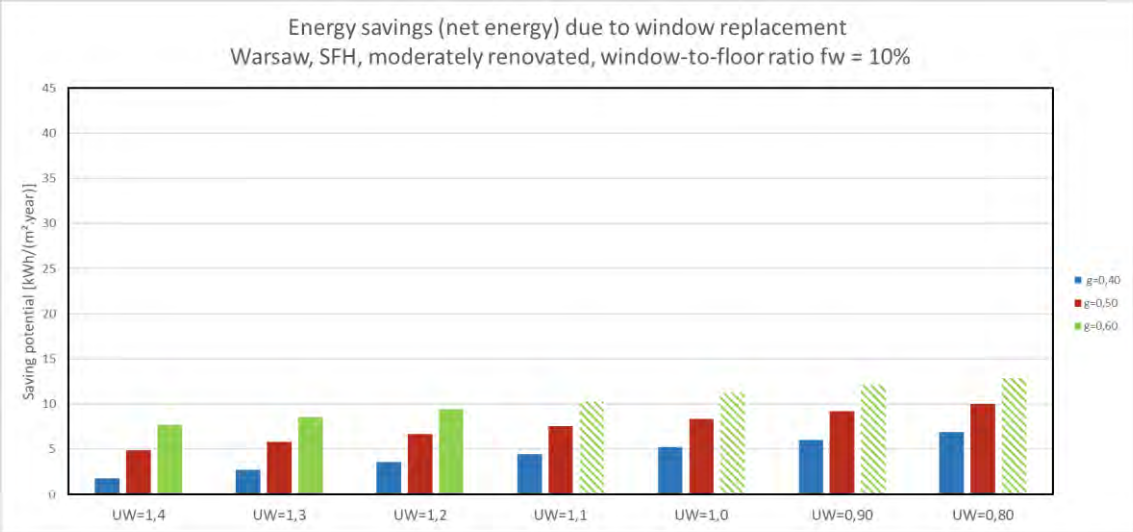


Figure C-7: Net-energy savings for a single-family-house in Warsaw, base case 2, window-to-floor ratio of 10 %

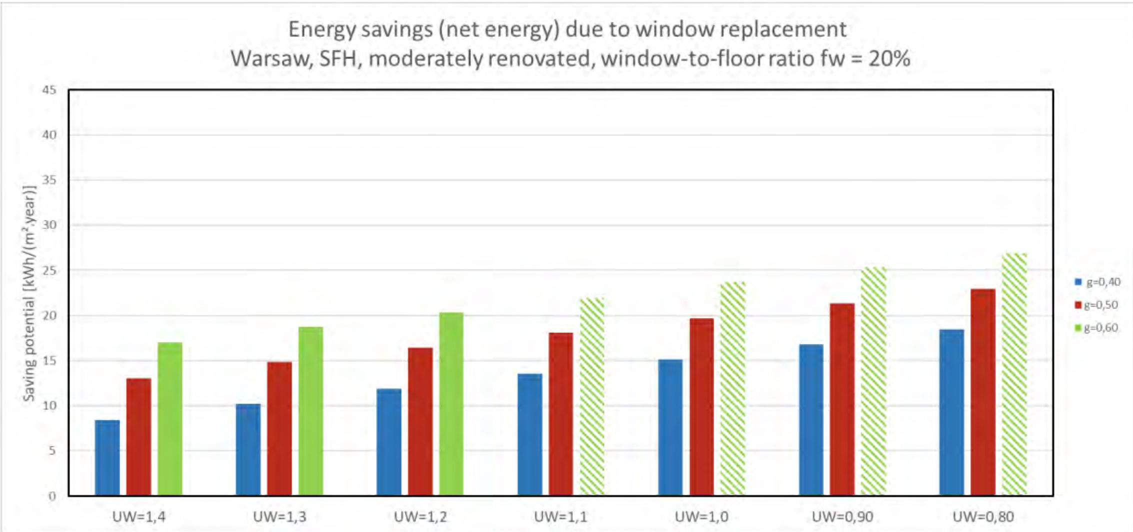


Figure C-8: Net-energy savings for a single -family-house in Warsaw, base case 2, window-to-floor ratio of 20 %

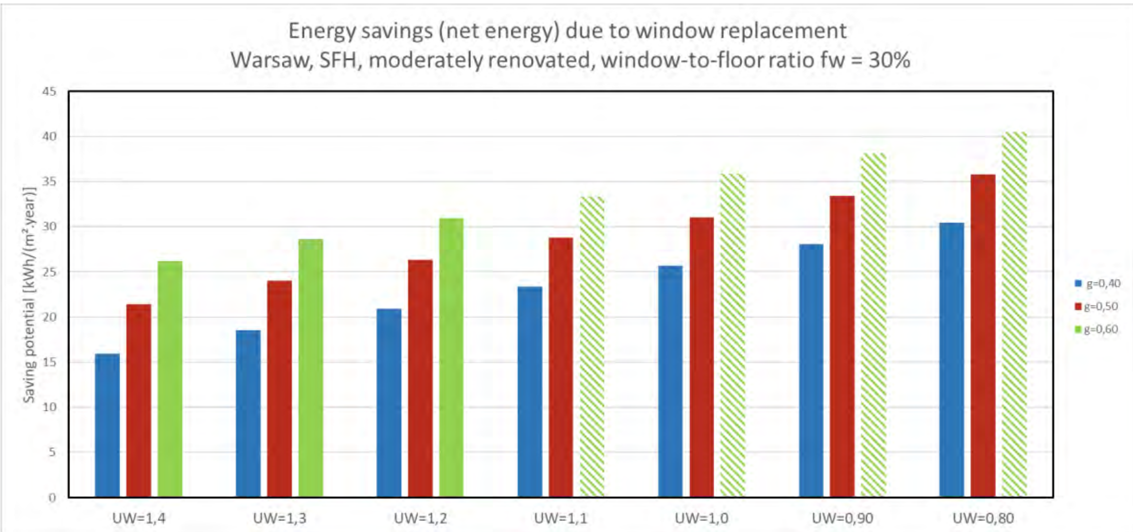


Figure C-9: Net-energy savings for a single -family-house in Warsaw, base case 2, window-to-floor ratio of 30 %

C 1 Base case 2, MFH

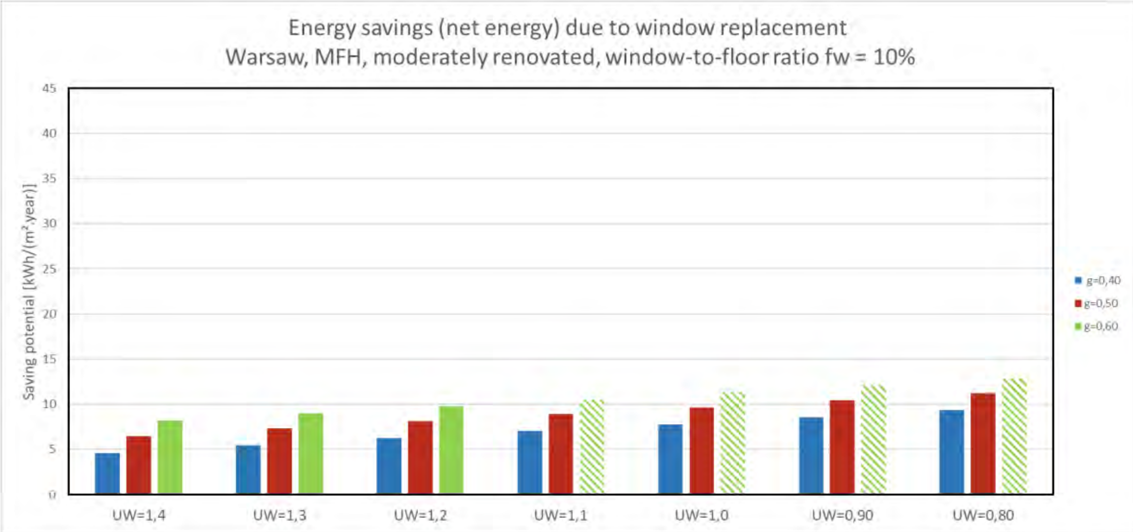


Figure C-10: Net-energy savings for a multi-family-house in Warsaw, base case 1, window-to-floor ratio of 10 %

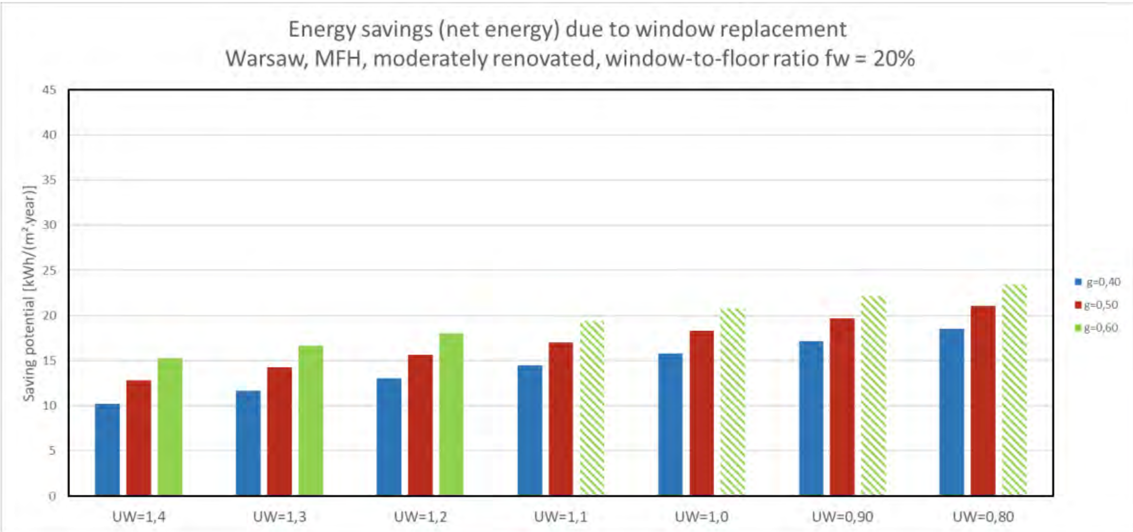


Figure C-11: Net-energy savings for a multi -family-house in Warsaw, base case 1, window-to-floor ratio of 20 %

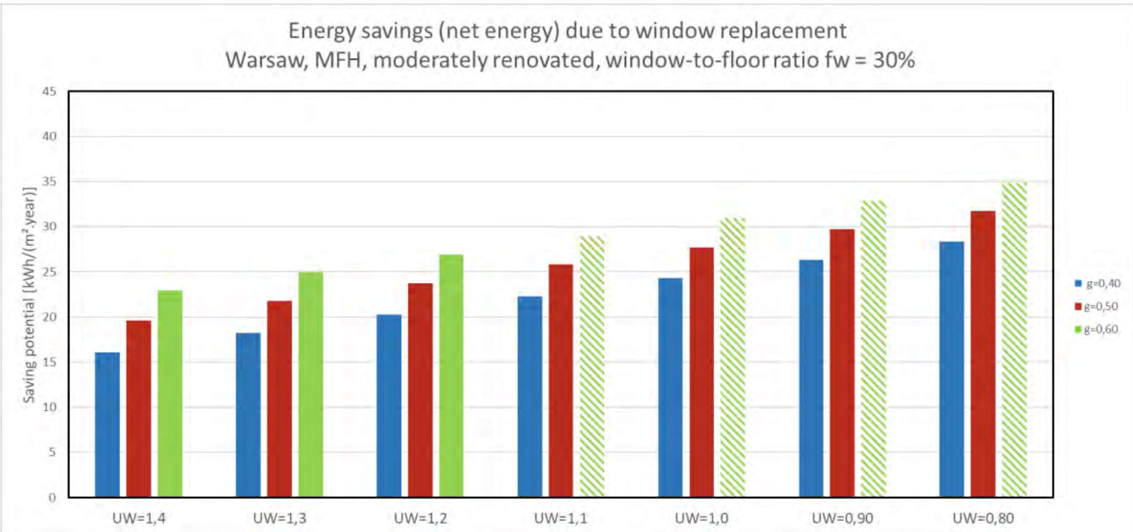


Figure C-12: Net-energy savings for a multi -family-house in Warsaw, base case 1, window-to-floor ratio of 30 %

Appendix D Saving results for all EU-countries (window-to-floor ratio: 20 %)

D 1 Austria

D 1.1 Results building level (net energy)

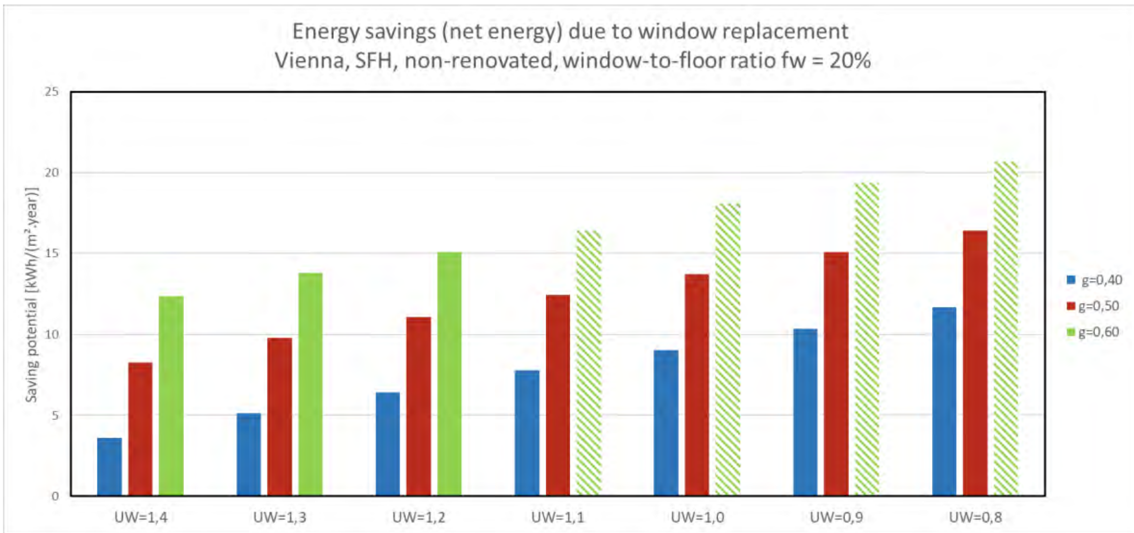


Figure D-1: Net energy savings for SFH, base case 1

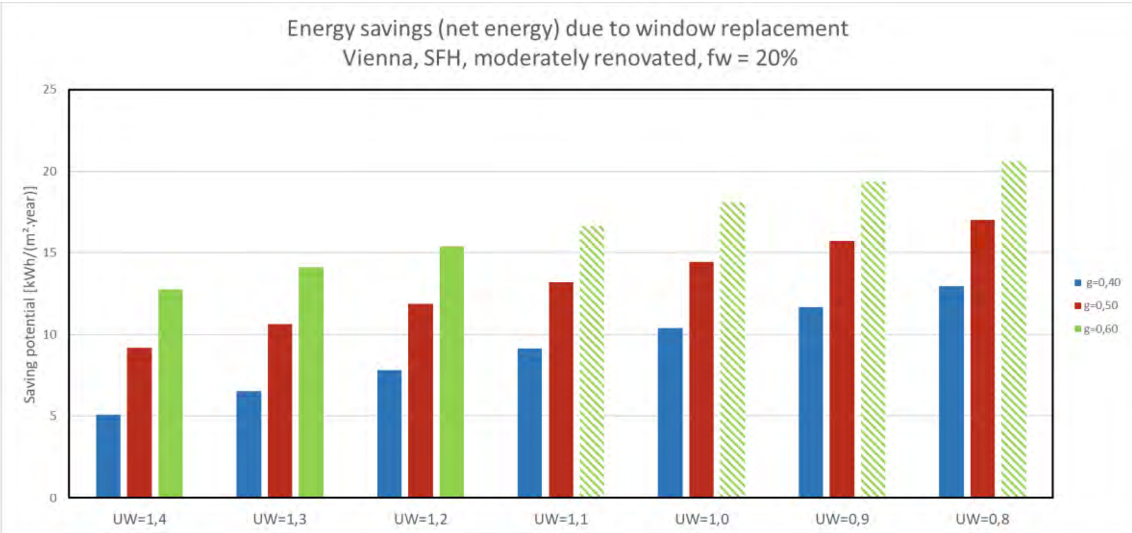


Figure D-2: Net energy savings for SFH, base case 2

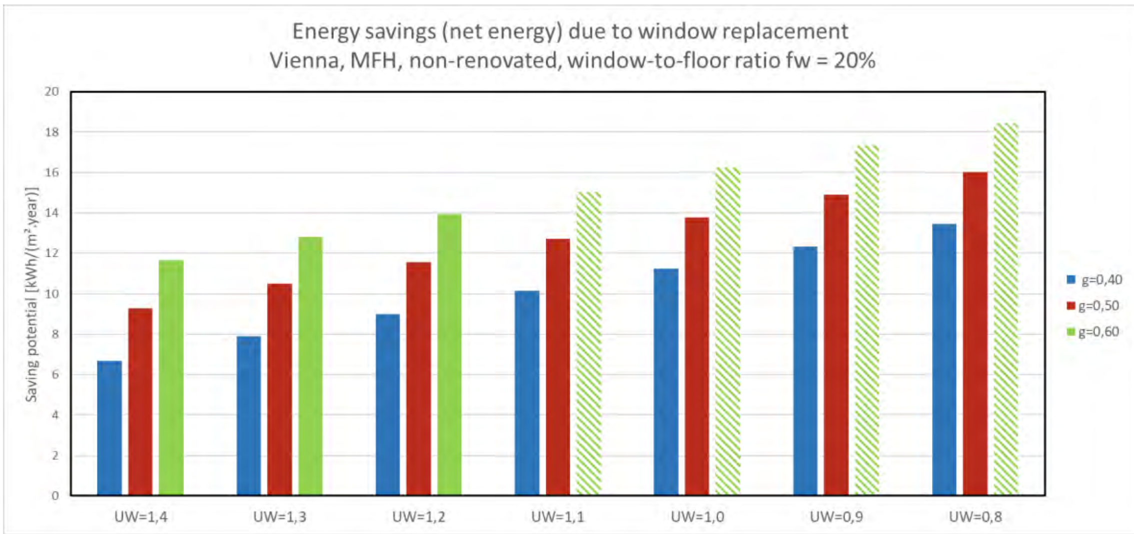


Figure D-3: Net energy savings for MFH, base case 1

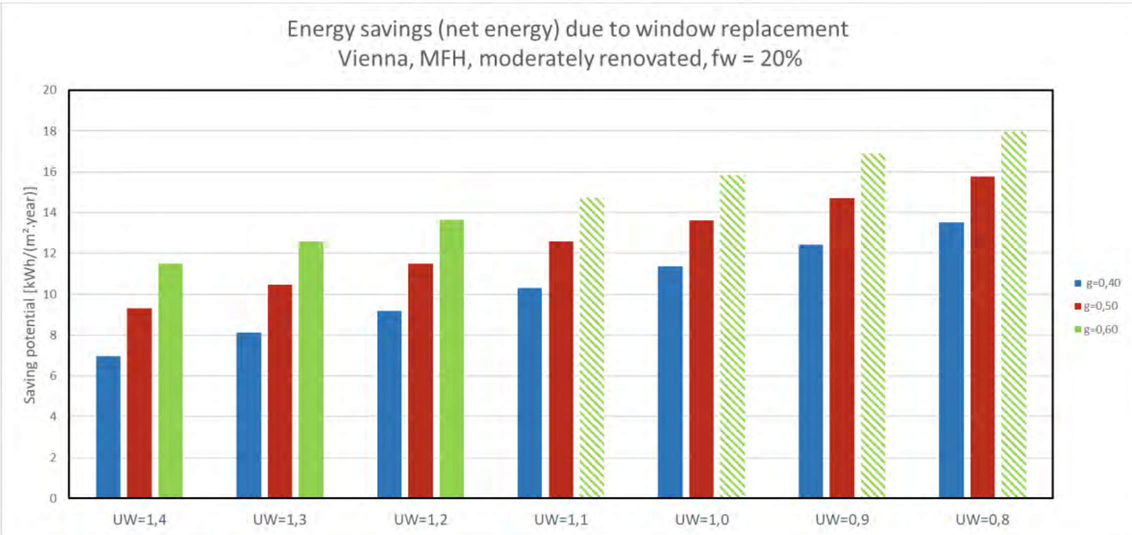


Figure D-4: Net energy savings for MFH, base case 2

D 1.2 Results national level (final energy and CO_2-savings)

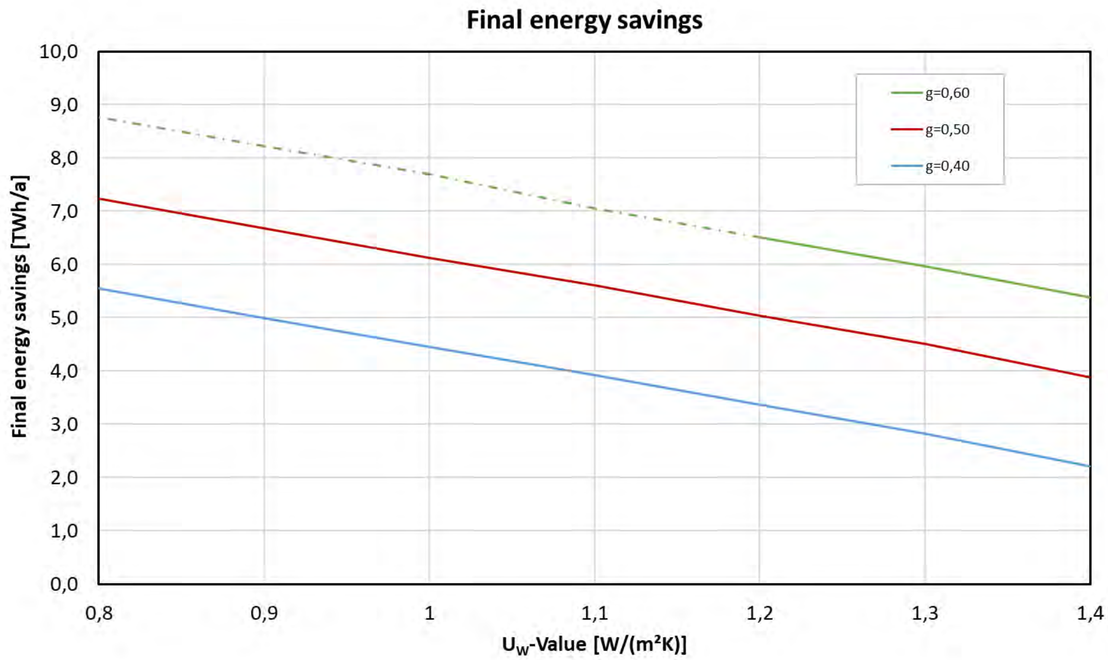


Figure D-5: Final energy savings Austria

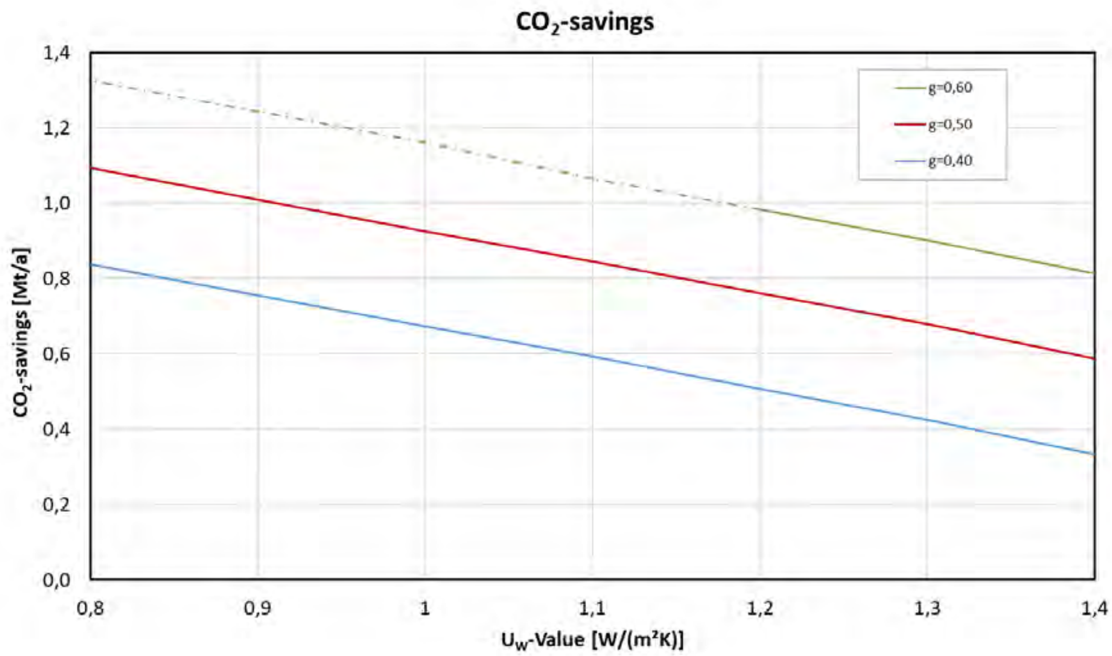


Figure D-6: CO_2-emission savings Austria

D 2 Belgium

D 2.1 Results building level (net energy)

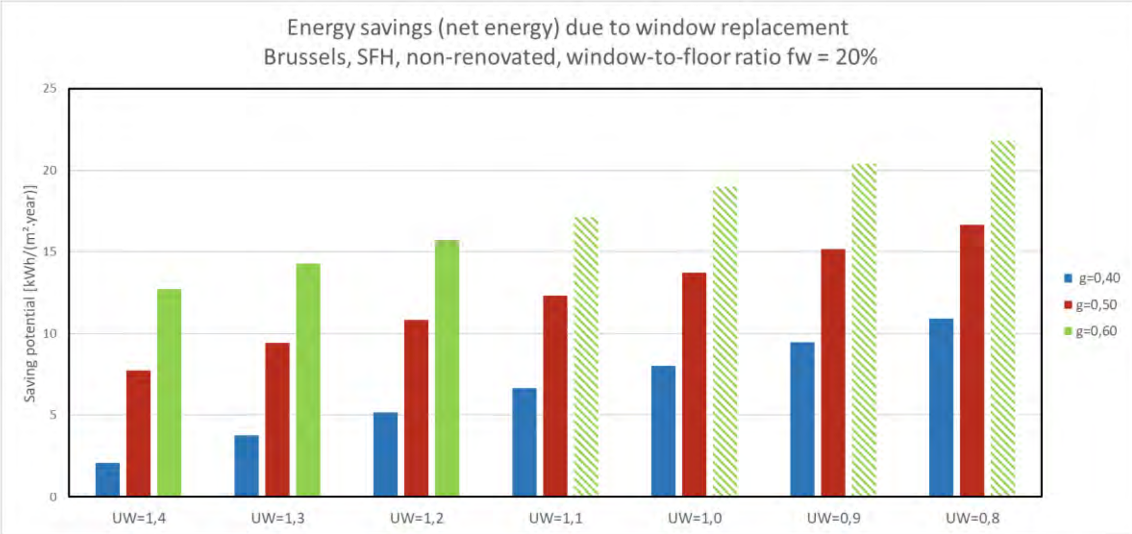


Figure D-7: Net energy savings for SFH, base case 1

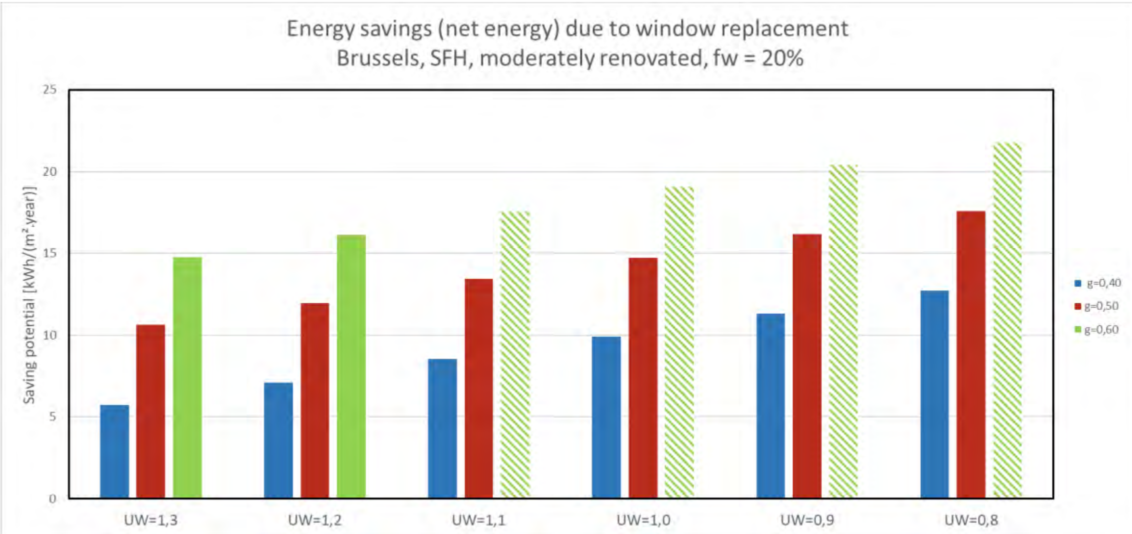


Figure D-8: Net energy savings for SFH, base case 2

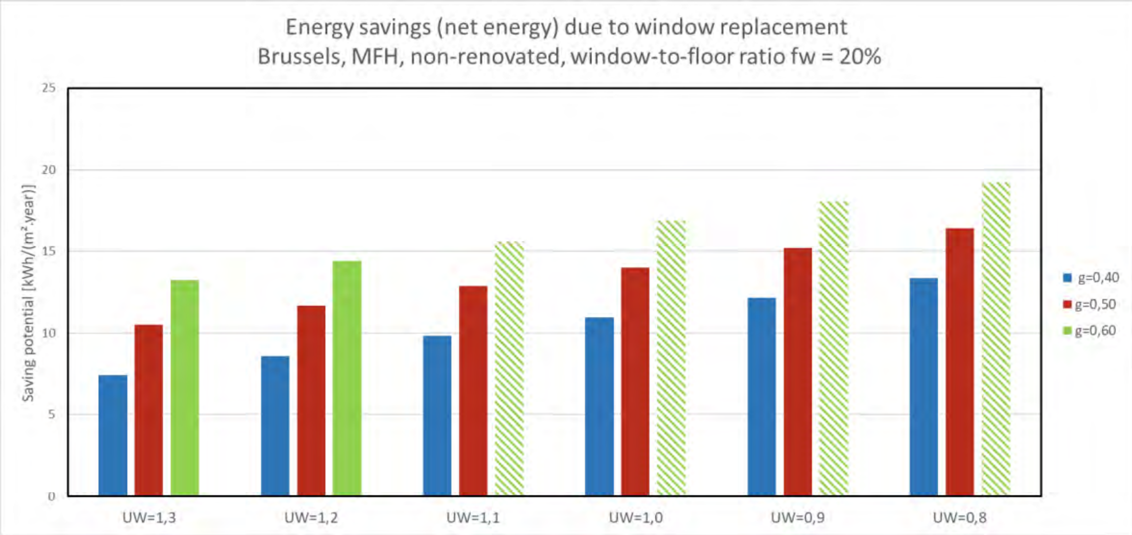


Figure D-9: Net energy savings for MFH, base case 1

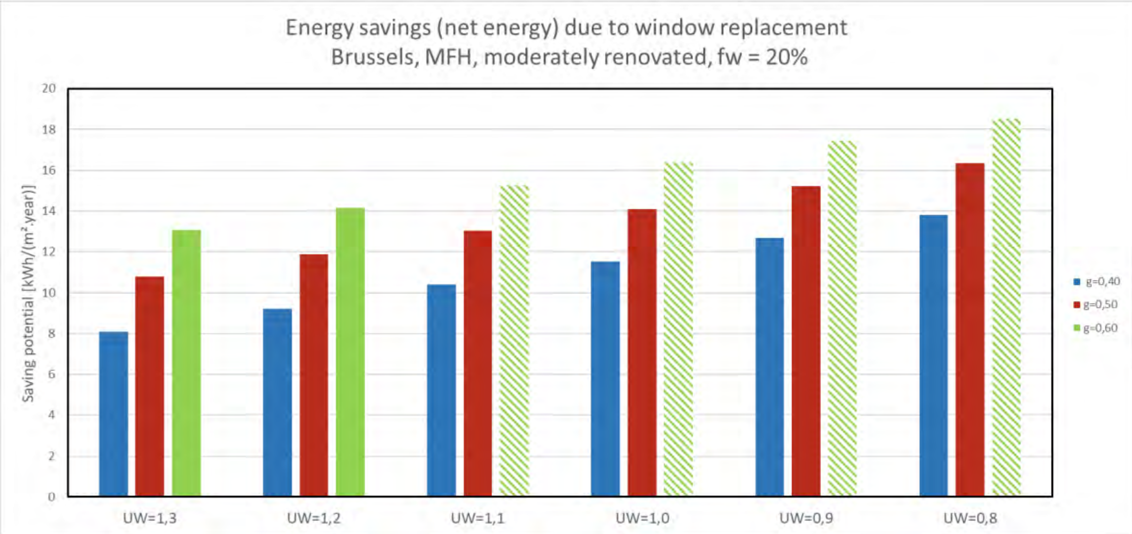


Figure D-10: Net energy savings for MFH, base case 2

D 2.2 Results national level (final energy and CO_2-savings)

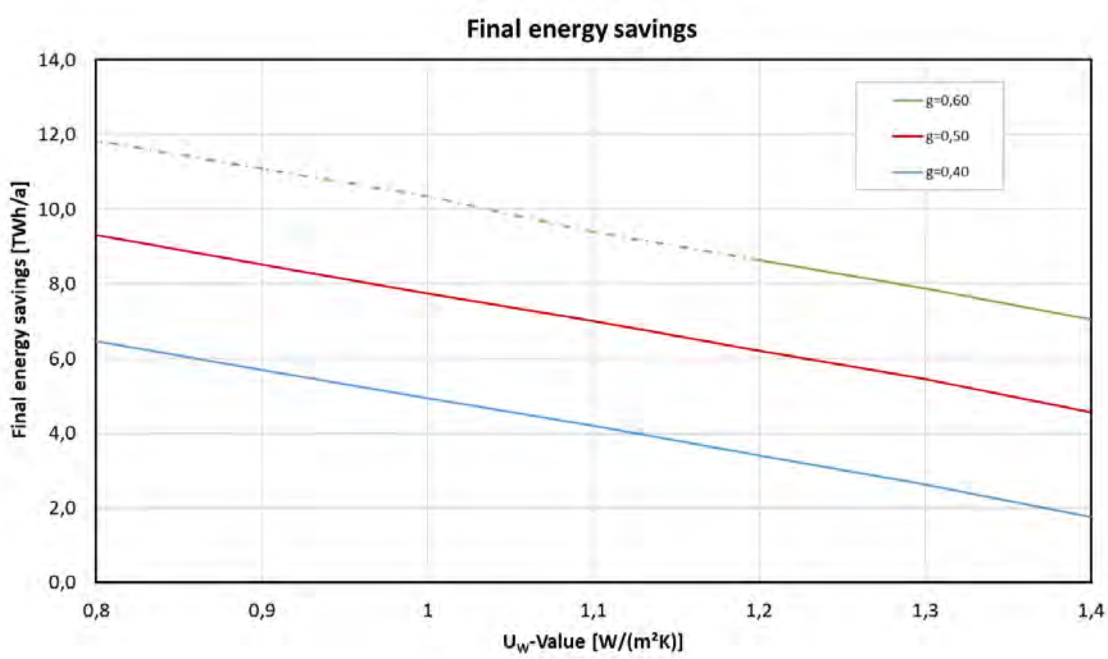


Figure D-11: Final energy savings Belgium

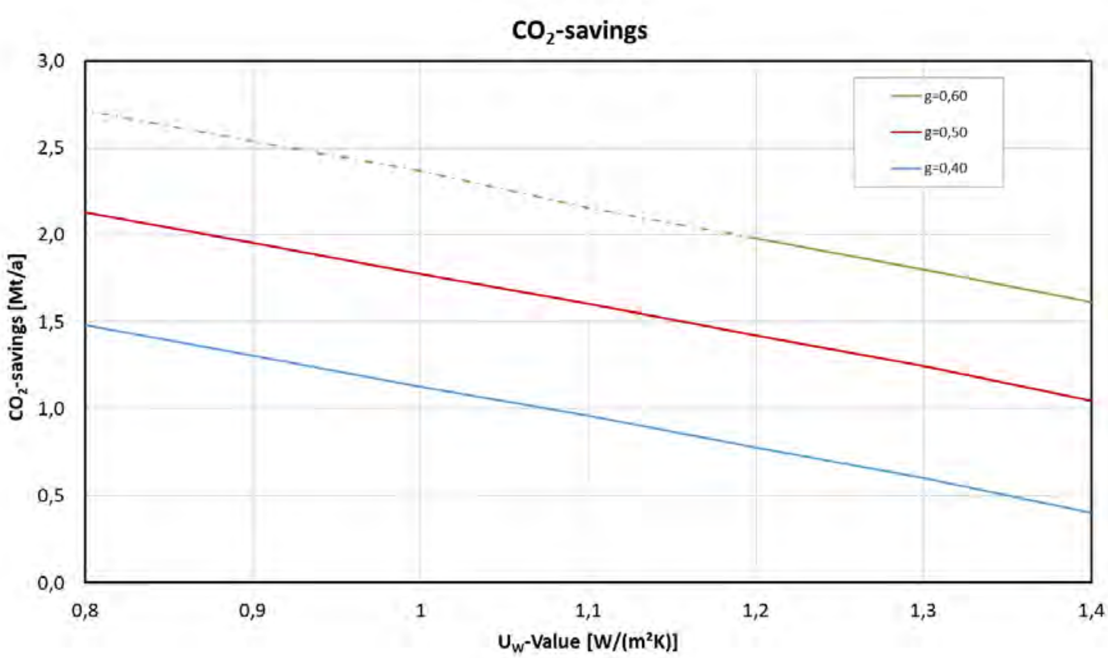


Figure D-12: CO_2-emission savings Belgium

D 3 Bulgaria

D 3.1 Results building level (net energy)

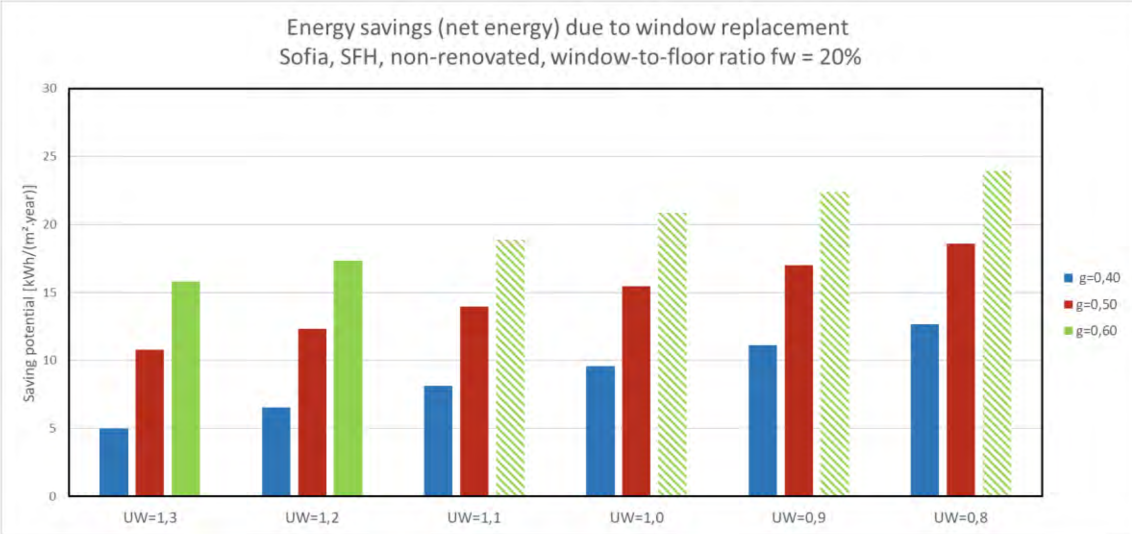


Figure D-13: Net energy savings for SFH, base case 1

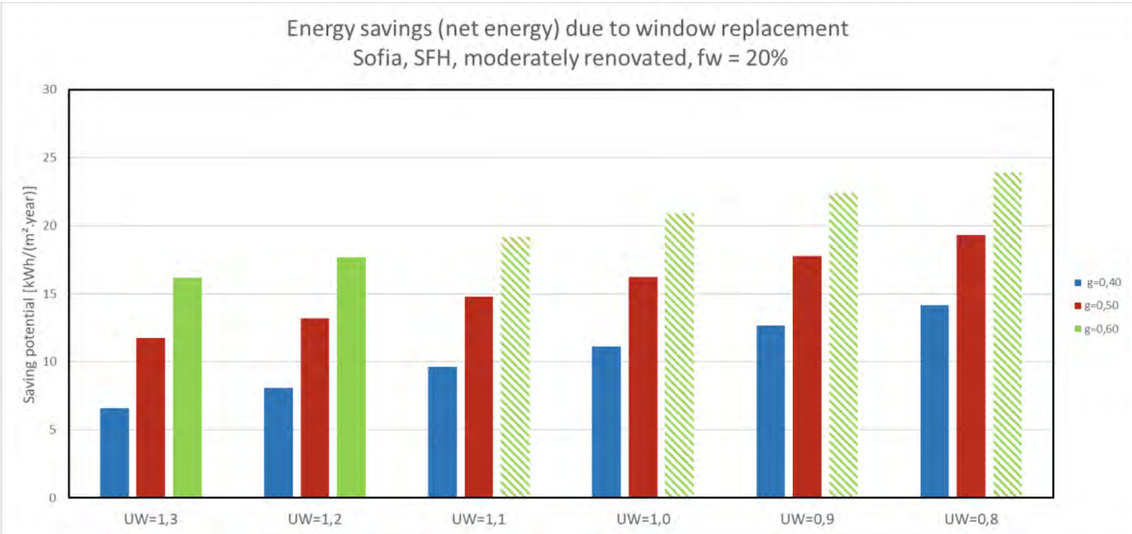


Figure D-14: Net energy savings for SFH, base case 2

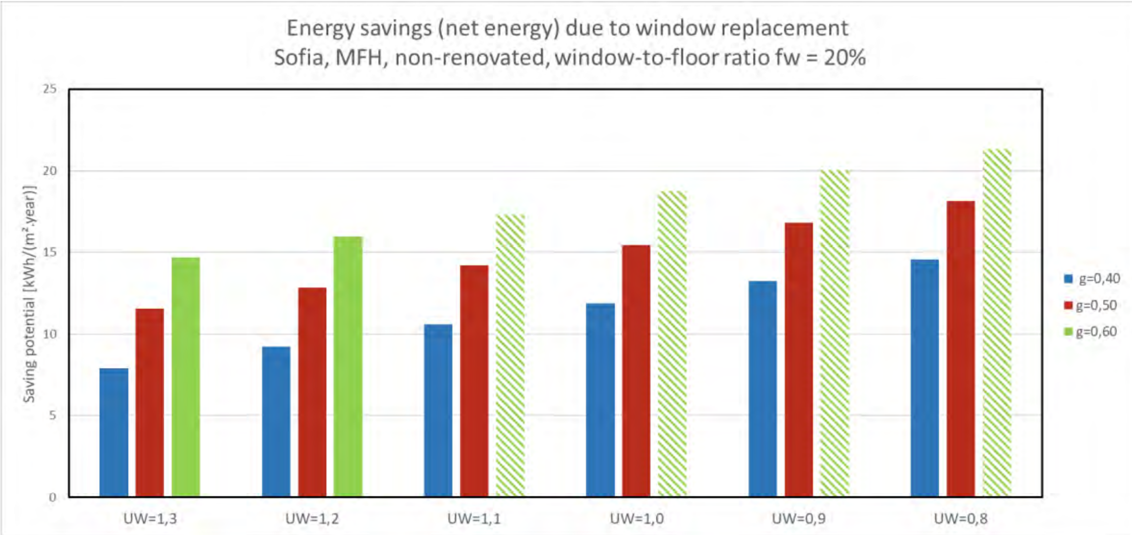


Figure D-15: Net energy savings for MFH, base case 1

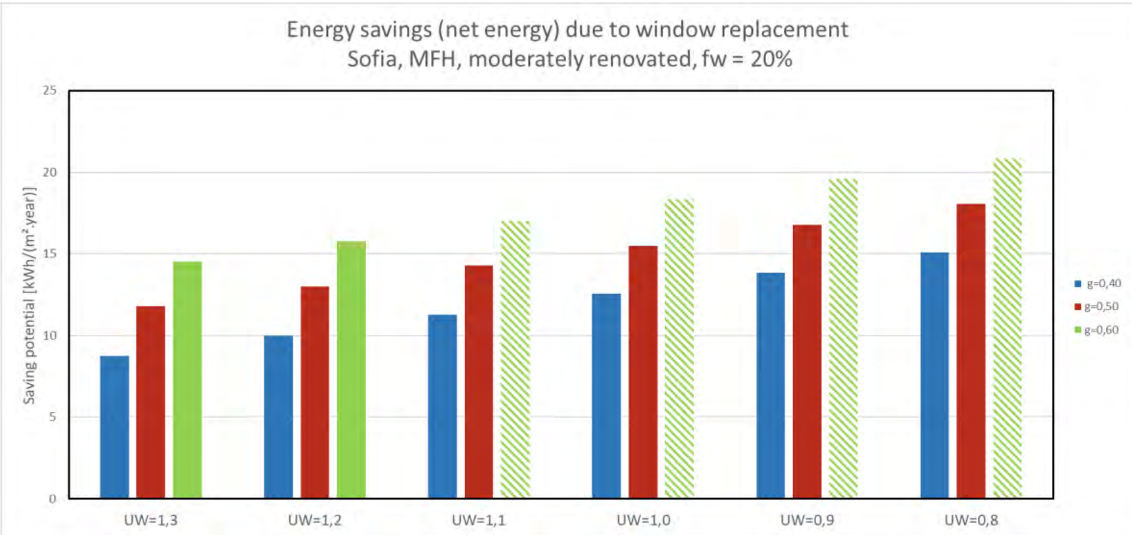


Figure D-16: Net energy savings for MFH, base case 2

D 3.2 Results national level (final energy and CO_2-savings)

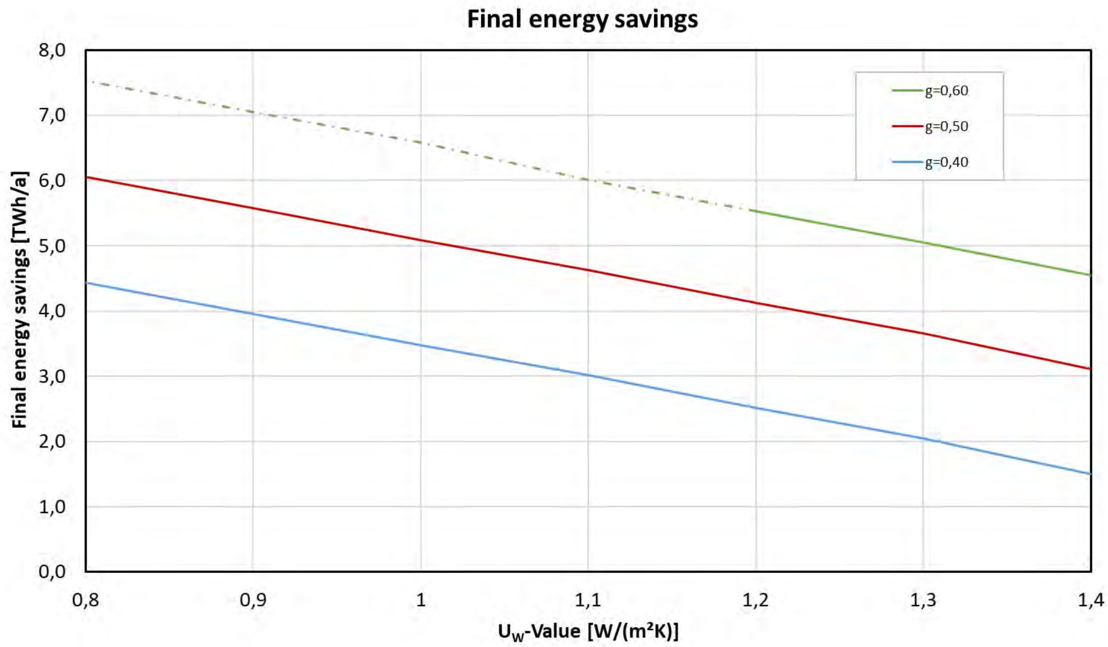


Figure D-17: Final energy savings Bulgaria

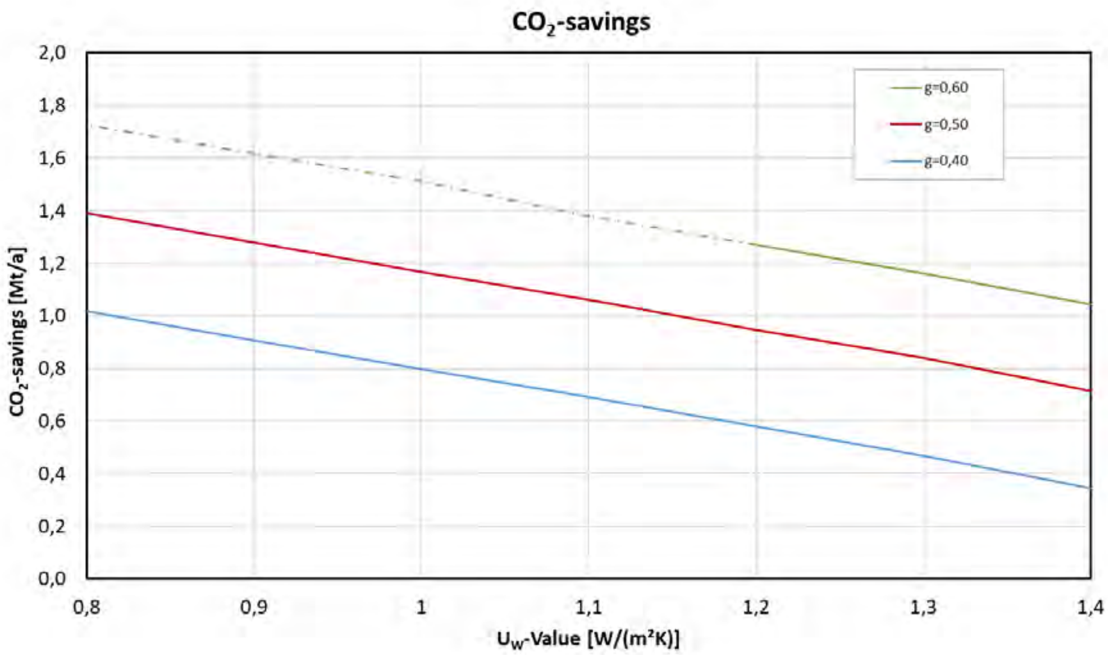


Figure D-18: CO_2-emission savings Bulgaria

D 4 Croatia

D 4.1 Results building level (net energy)

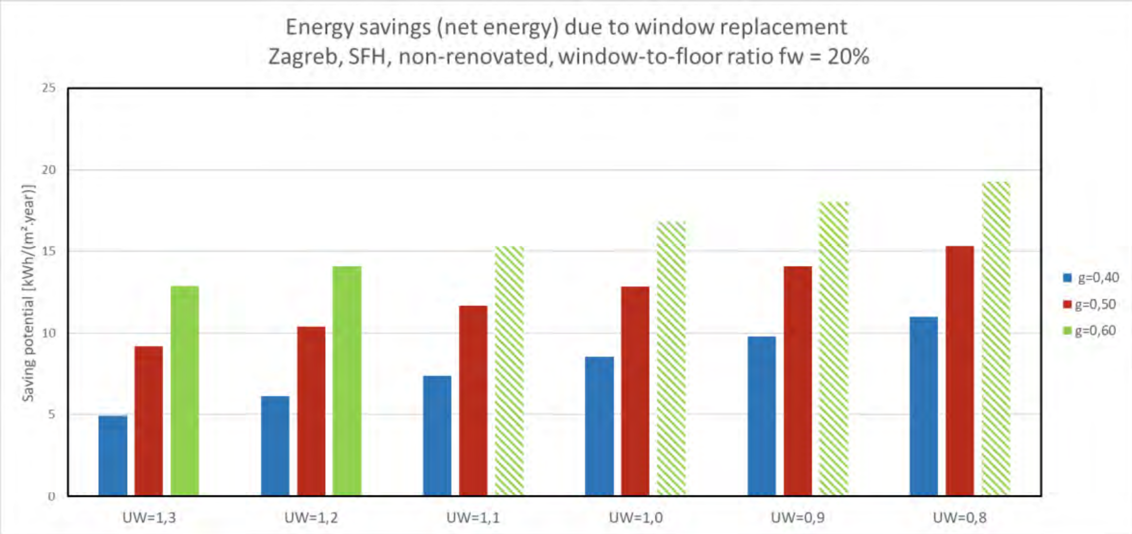


Figure D-19: Net energy savings for SFH, base case 1

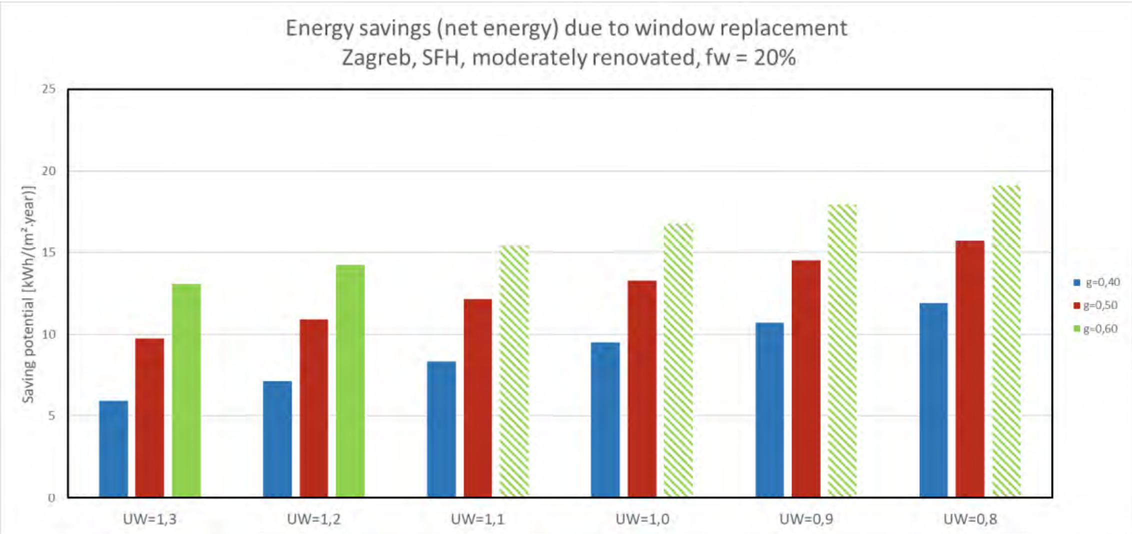


Figure D-20: Net energy savings for SFH, base case 2

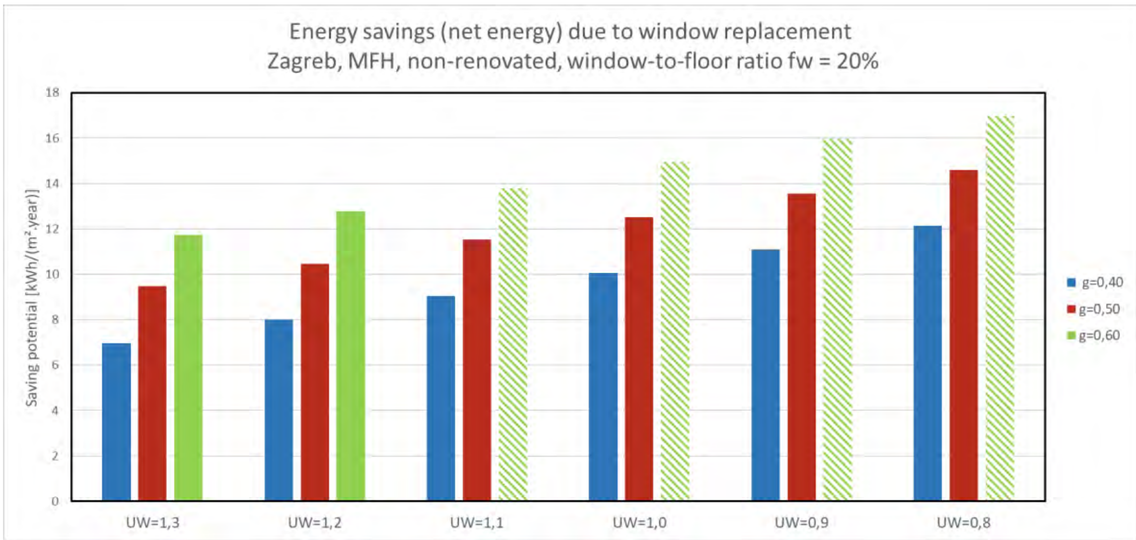


Figure D-21: Net energy savings for MFH, base case 1

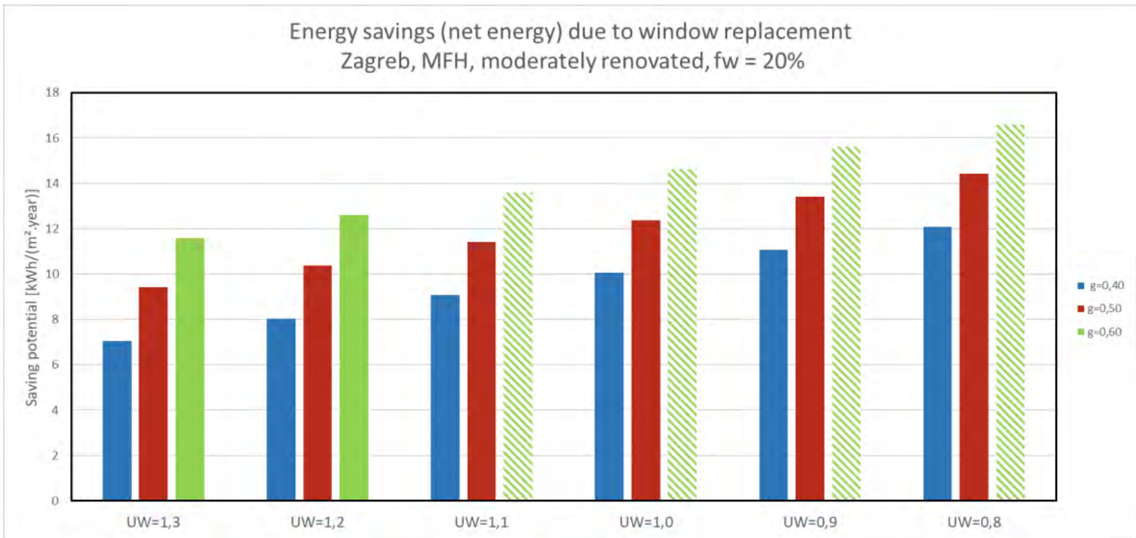


Figure D-22: Net energy savings for MFH, base case 2

D 4.2 Results national level (final energy and CO_2-savings)

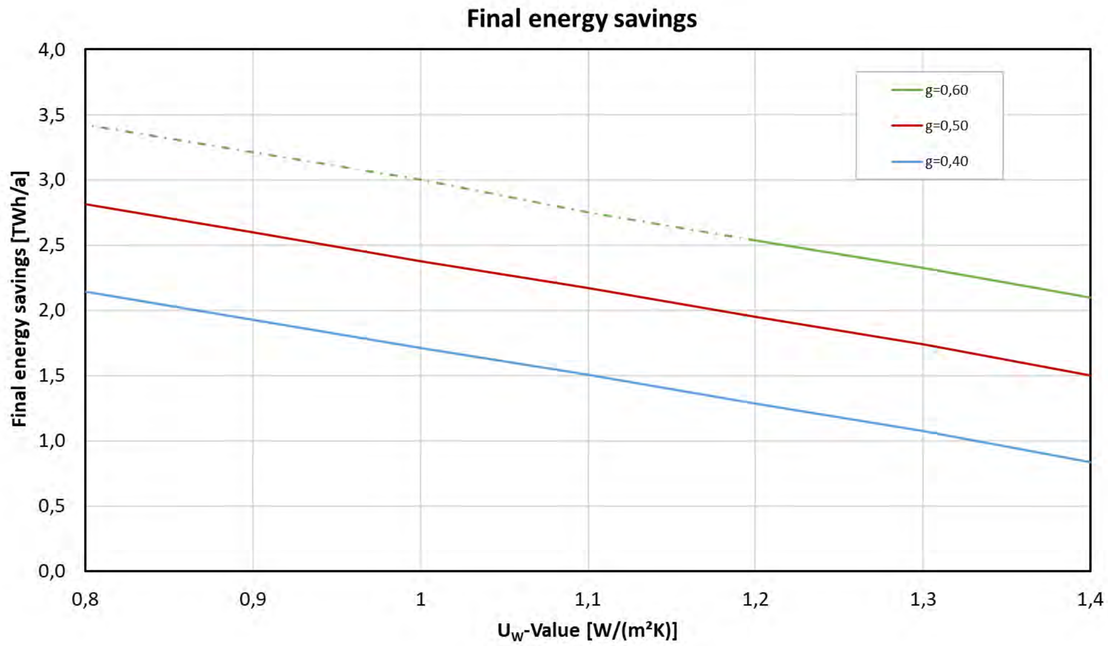


Figure D-23: Final energy savings Croatia

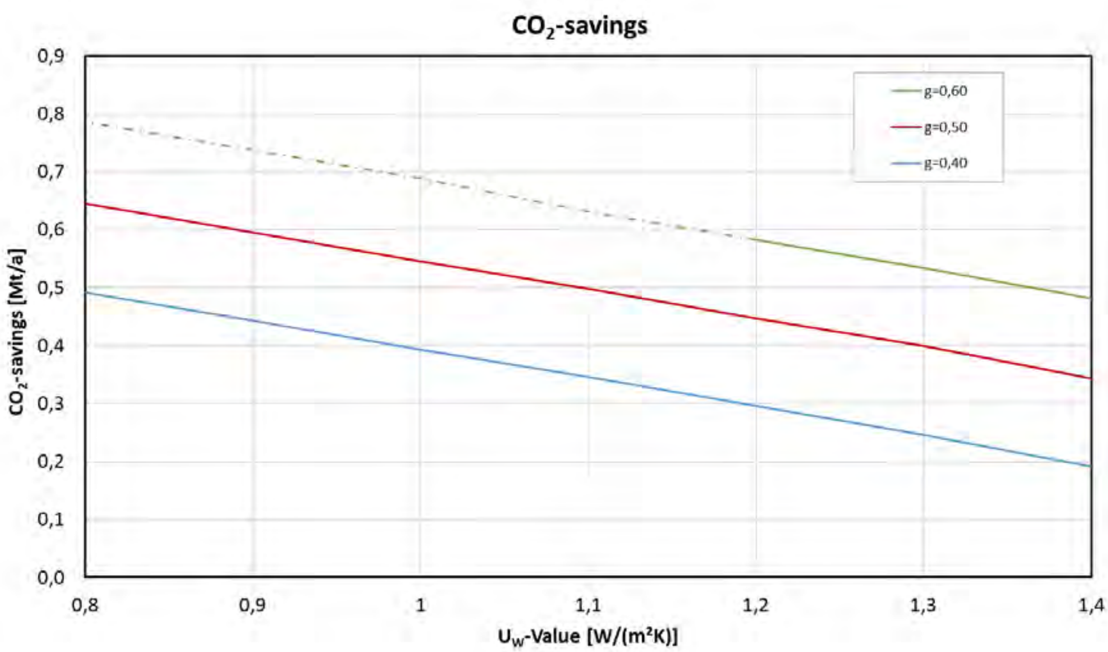


Figure D-24: CO_2-emission savings Croatia

D 5 Cyprus

D 5.1 Results building level (net energy)

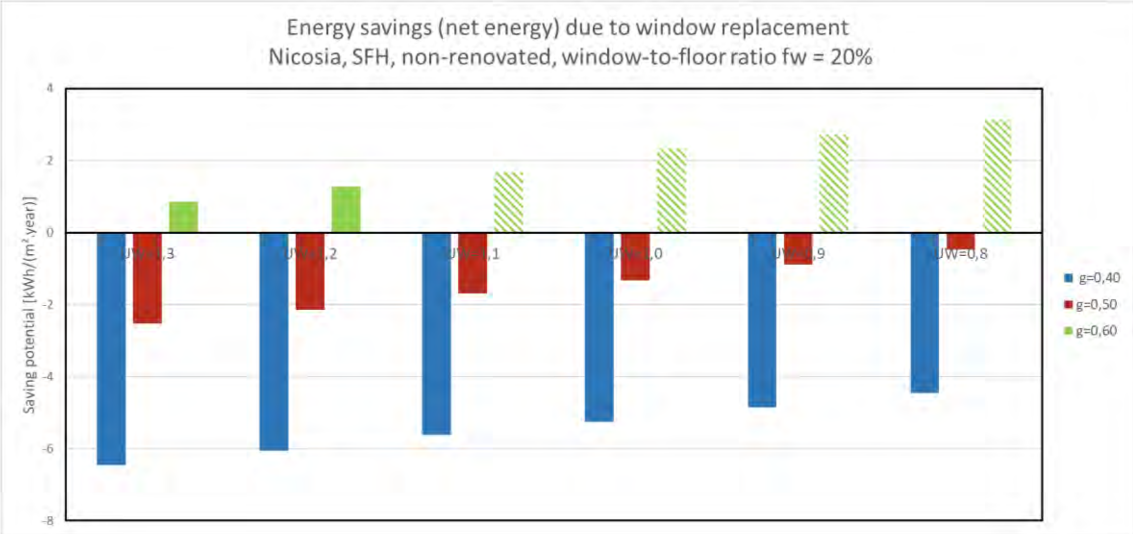


Figure D-25: Net energy savings for SFH, base case 1

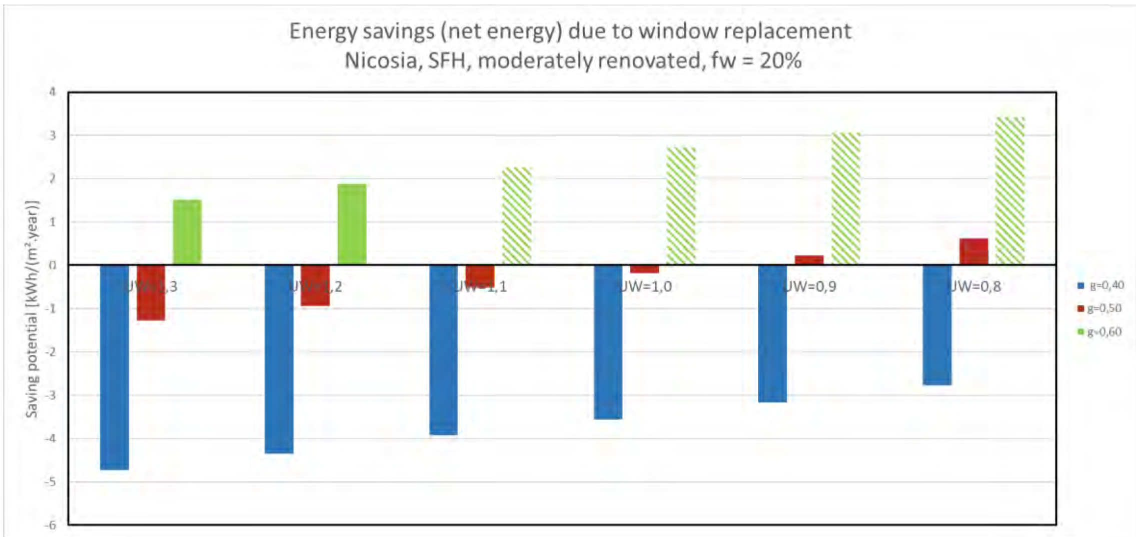


Figure D-26: Net energy savings for SFH, base case 2

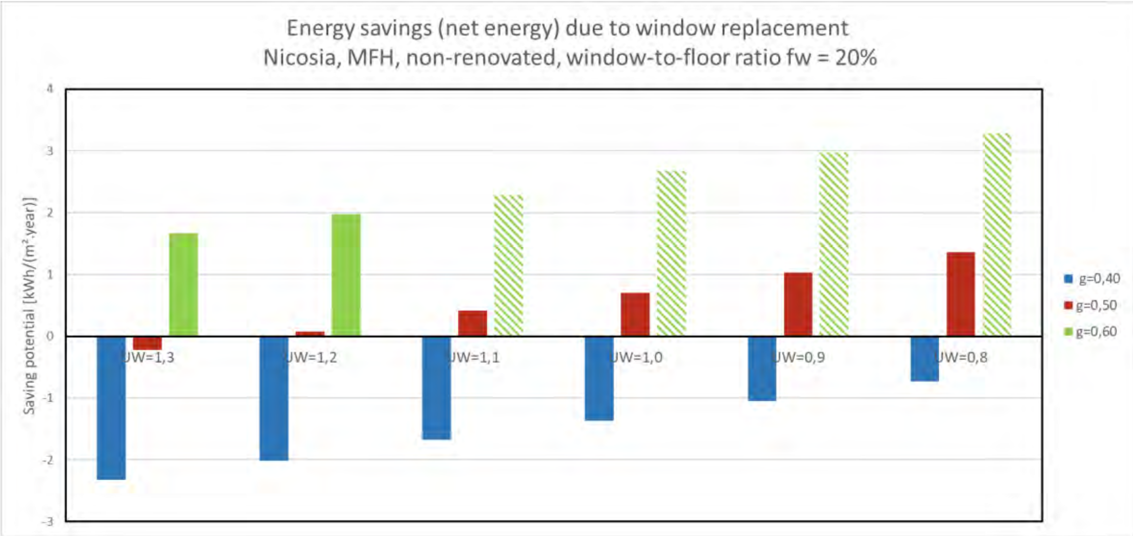


Figure D-27: Net energy savings for MFH, base case 1

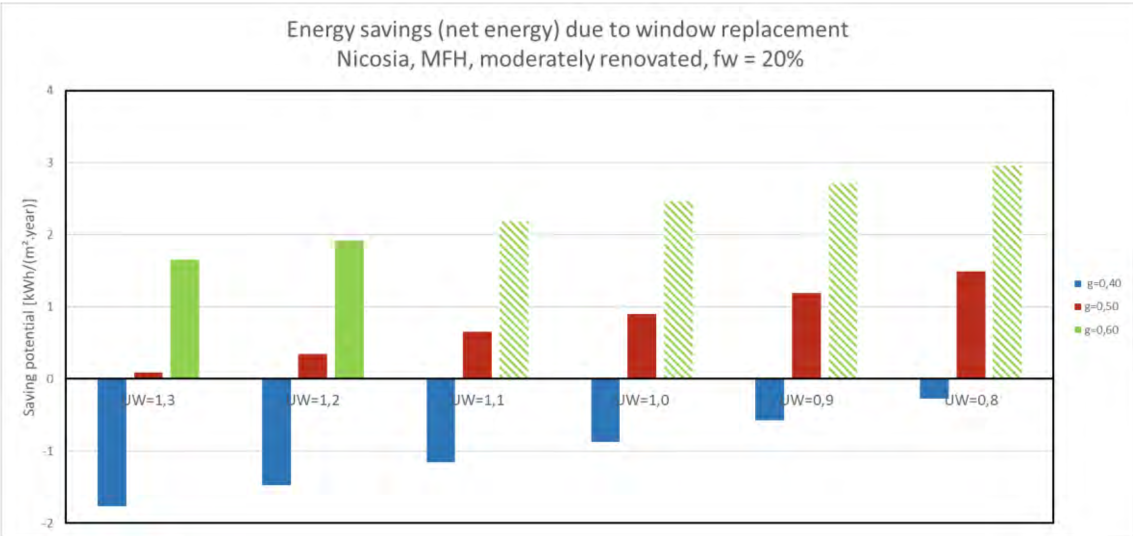


Figure D-28: Net energy savings for MFH, base case 2

D 5.2 Results national level (final energy and CO_2-savings)

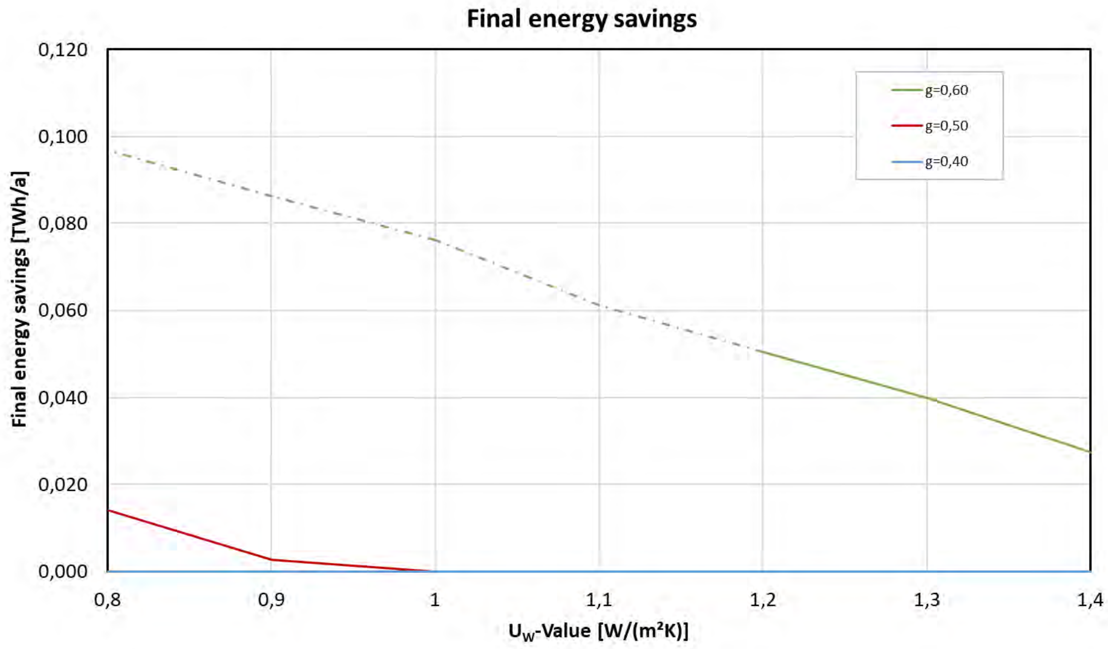


Figure D-29: Final energy savings Cyprus

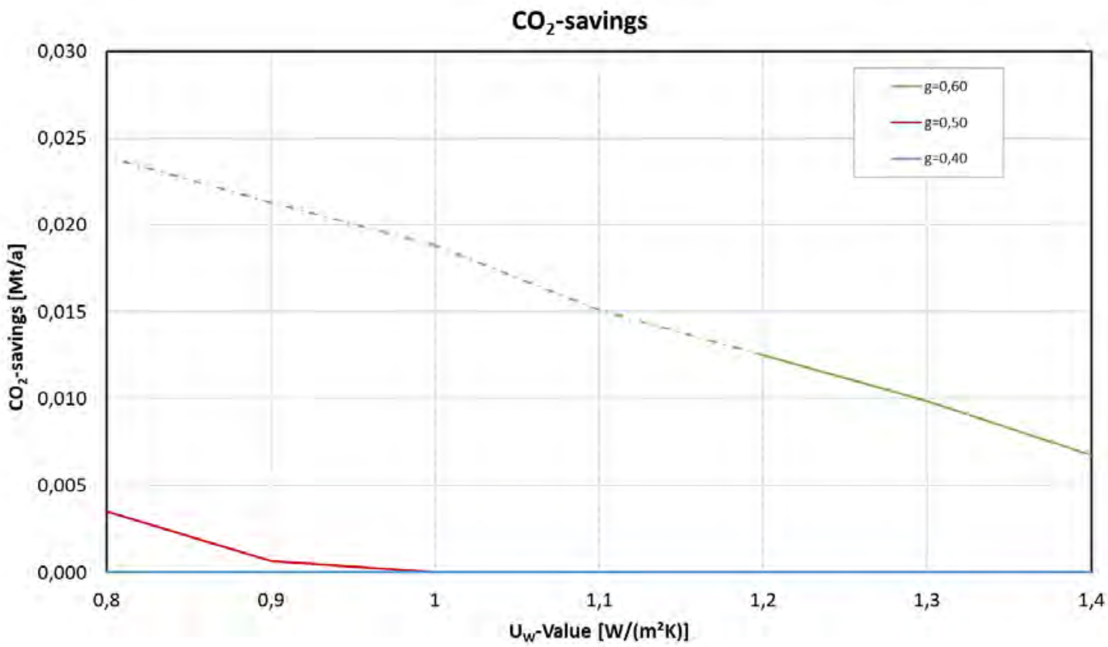


Figure D-30: CO_2-emission savings Cyprus

D 6 Czech Republic

D 6.1 Results building level (net energy)

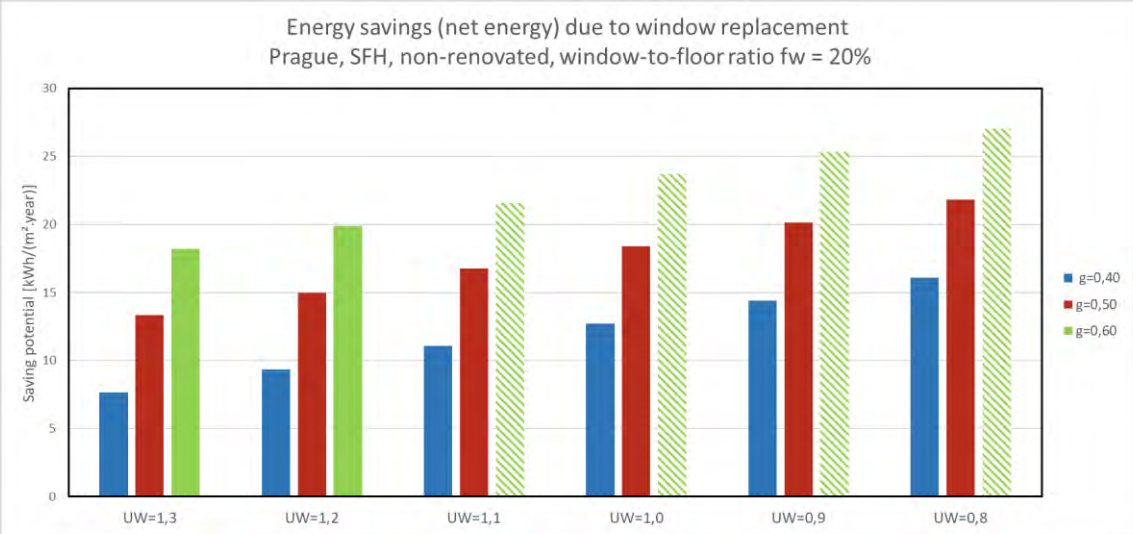


Figure D-31: Net energy savings for SFH, base case 1

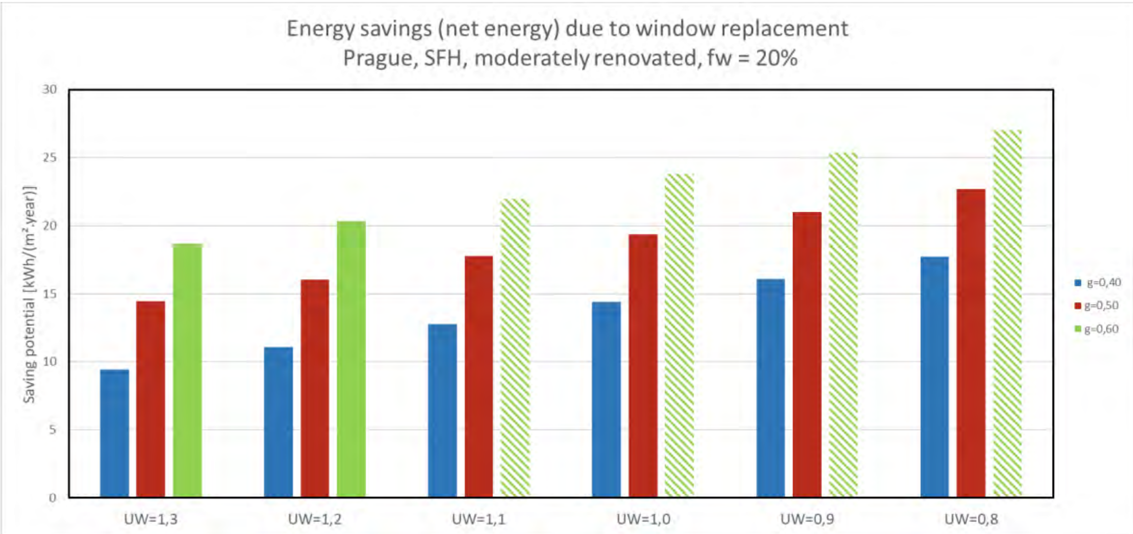


Figure D-32: Net energy savings for SFH, base case 2

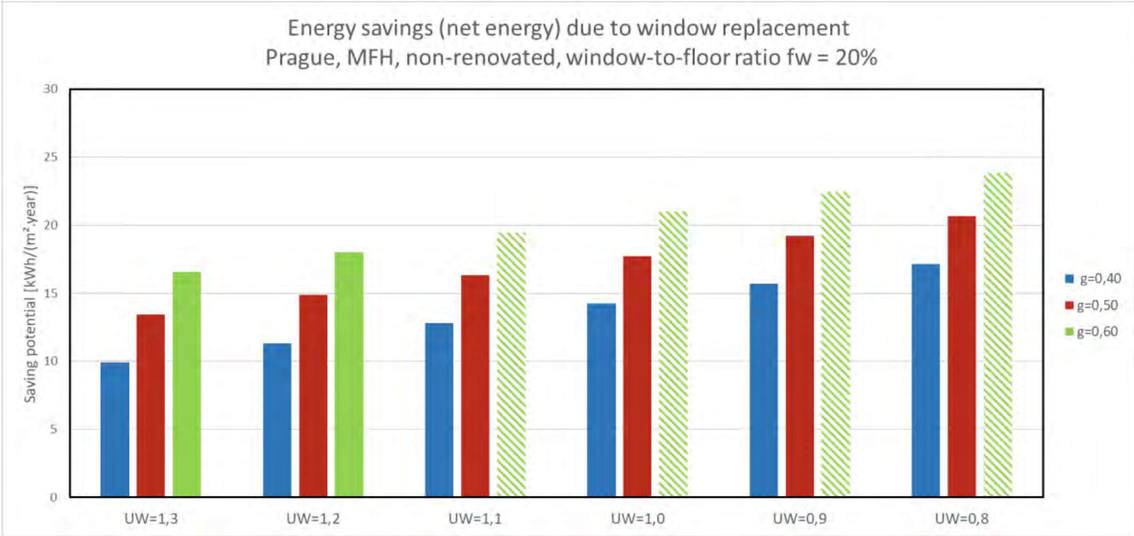


Figure D-33: Net energy savings for MFH, base case 1

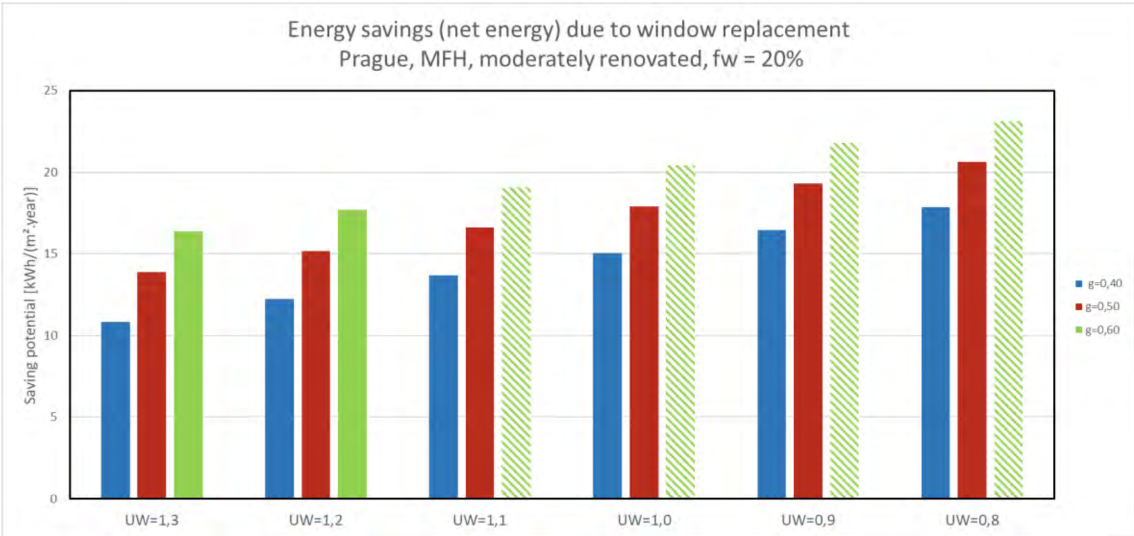


Figure D-34: Net energy savings for MFH, base case 2

D 6.2 Results national level (final energy and CO_2-savings)

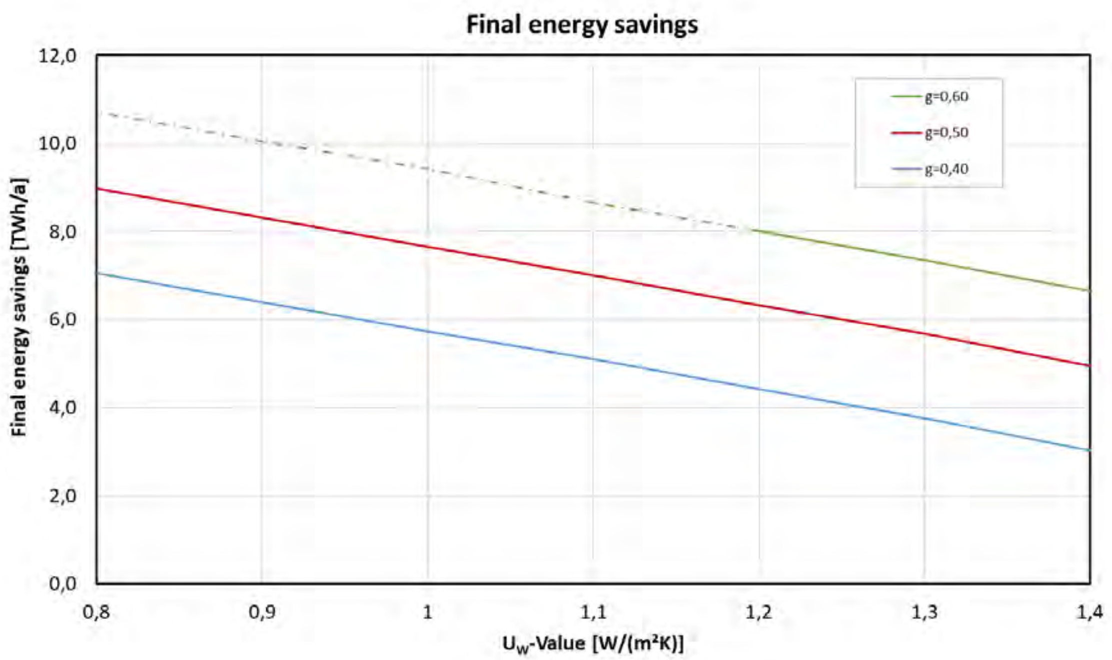


Figure D-35: Final energy savings Czech Republic

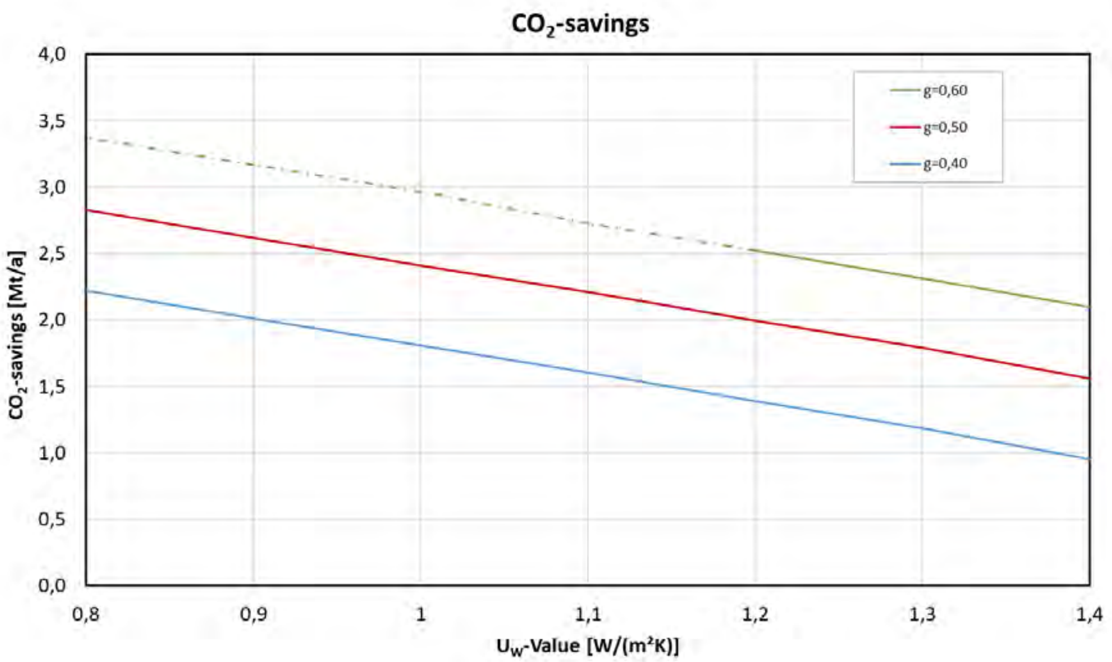


Figure D-36: CO_2-emission savings Czech Republic

D 7 Denmark

D 7.1 Results building level (net energy)

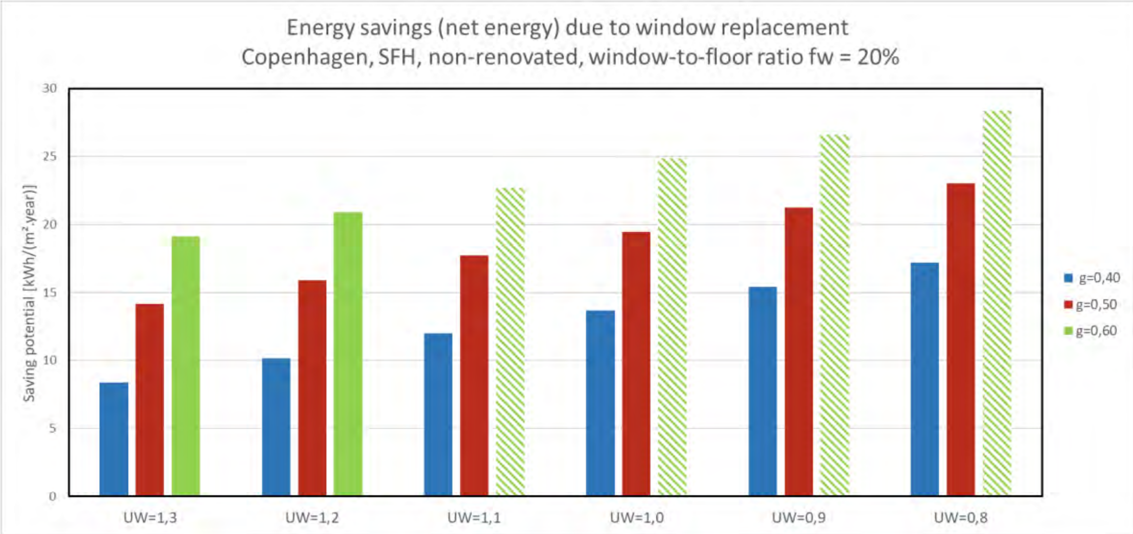


Figure D-37: Net energy savings for SFH, base case 1

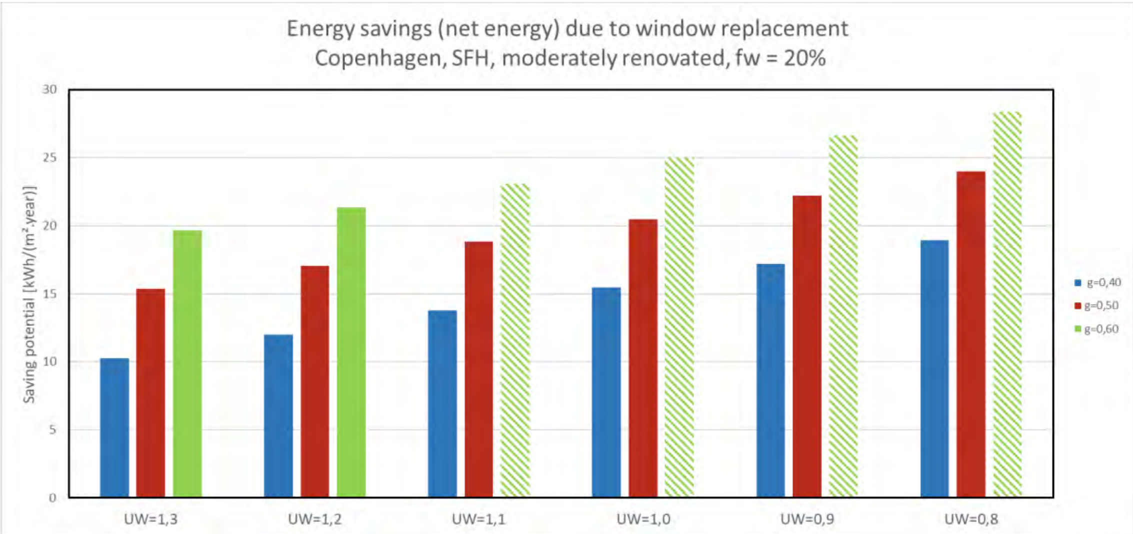


Figure D-38: Net energy savings for SFH, base case 2

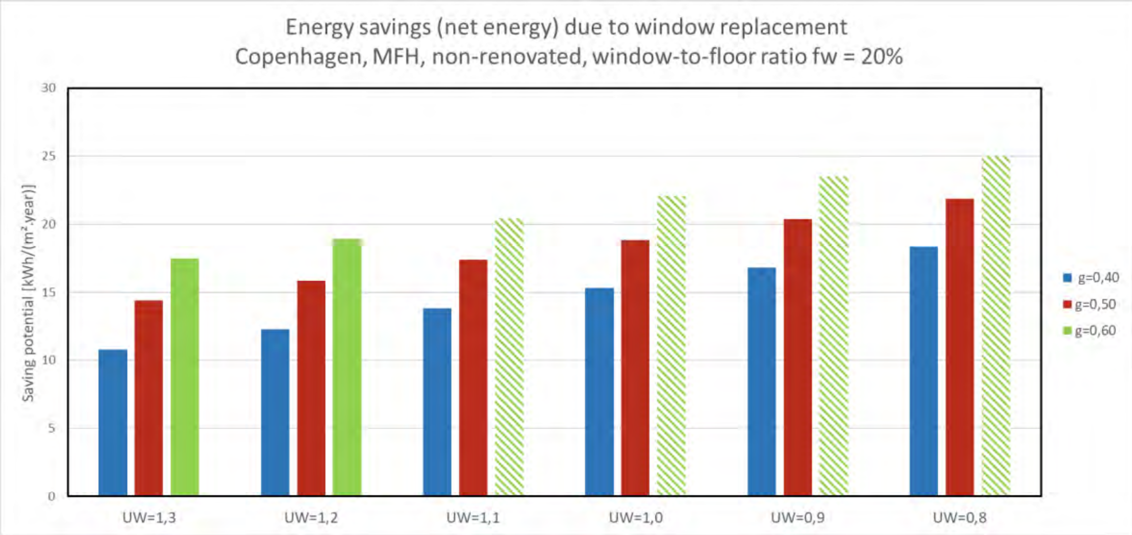


Figure D-39: Net energy savings for MFH, base case 1

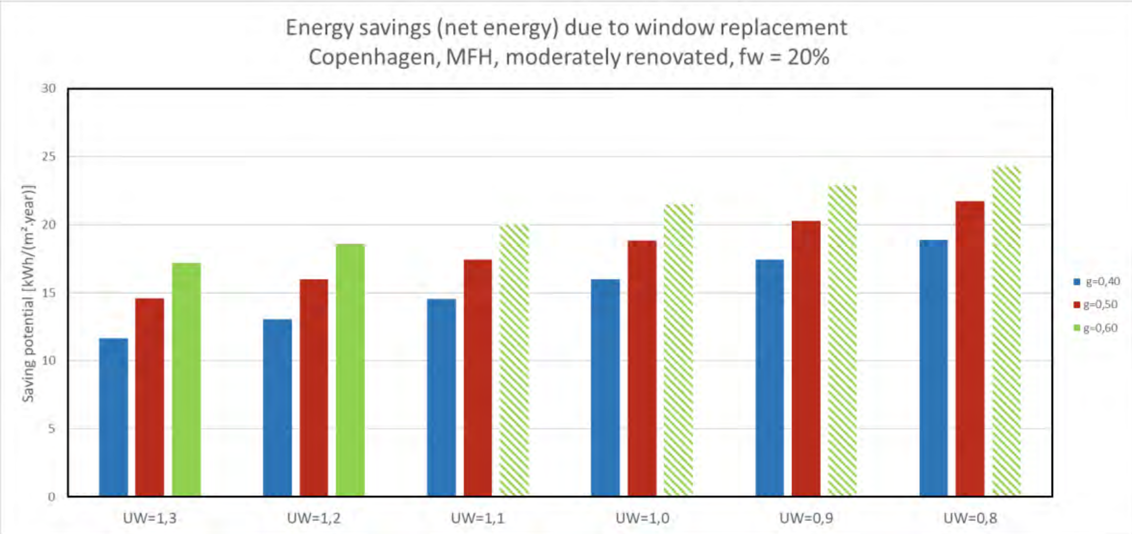


Figure D-40: Net energy savings for MFH, base case 2

D 7.2 Results national level (final energy and CO_2-savings)

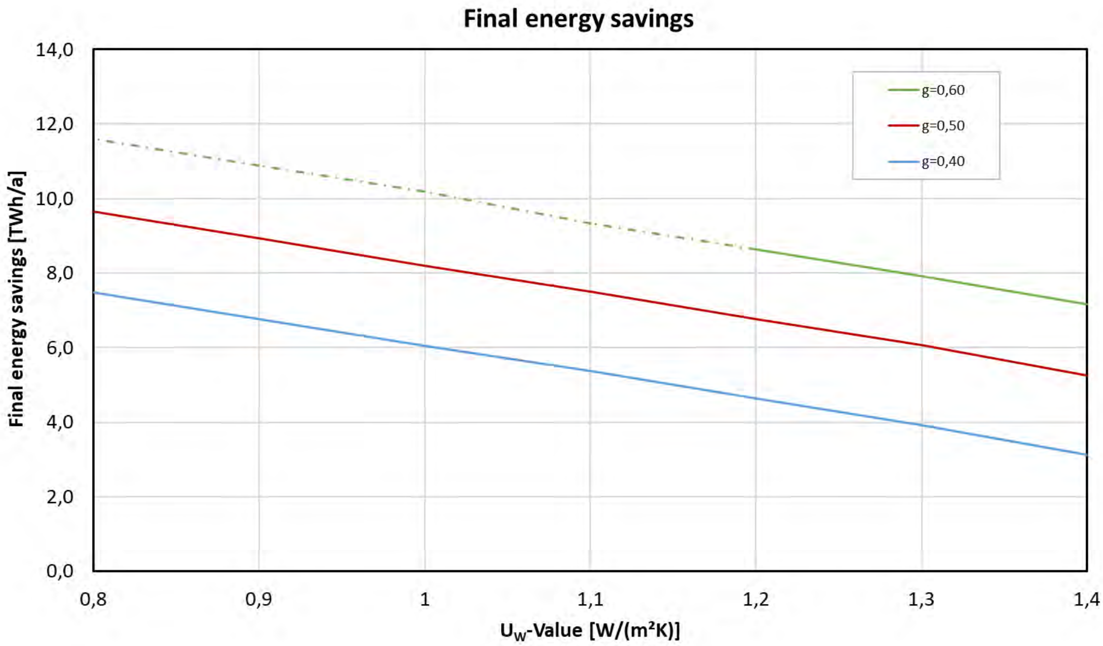


Figure D-41: Final energy savings Denmark

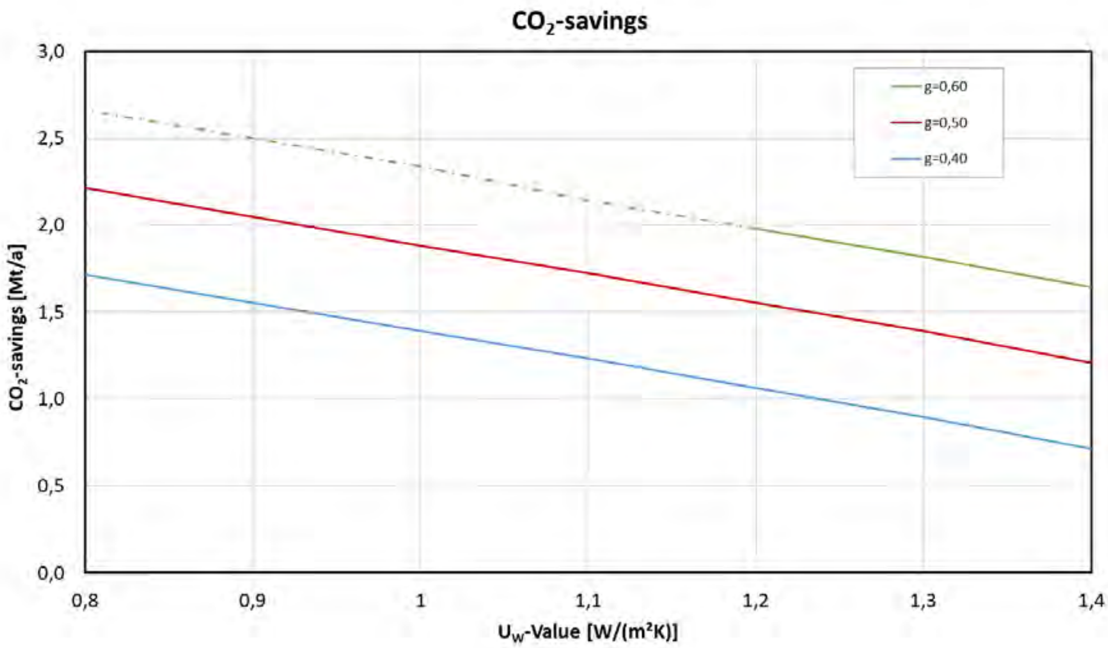


Figure D-42: CO_2-emission savings Denmark

D 8 Estonia

D 8.1 Results building level (net energy)

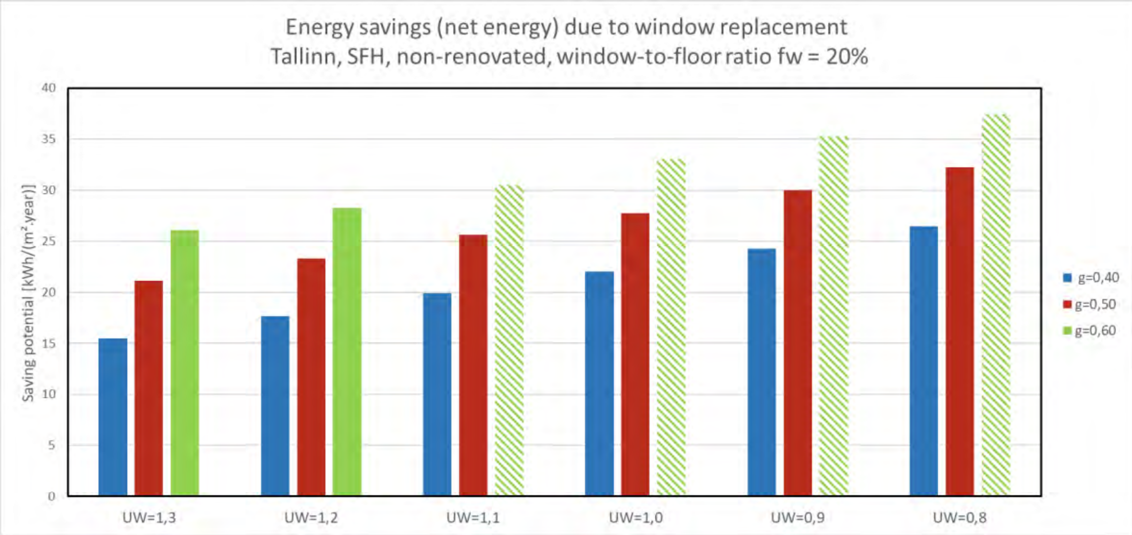


Figure D-43: Net energy savings for SFH, base case 1

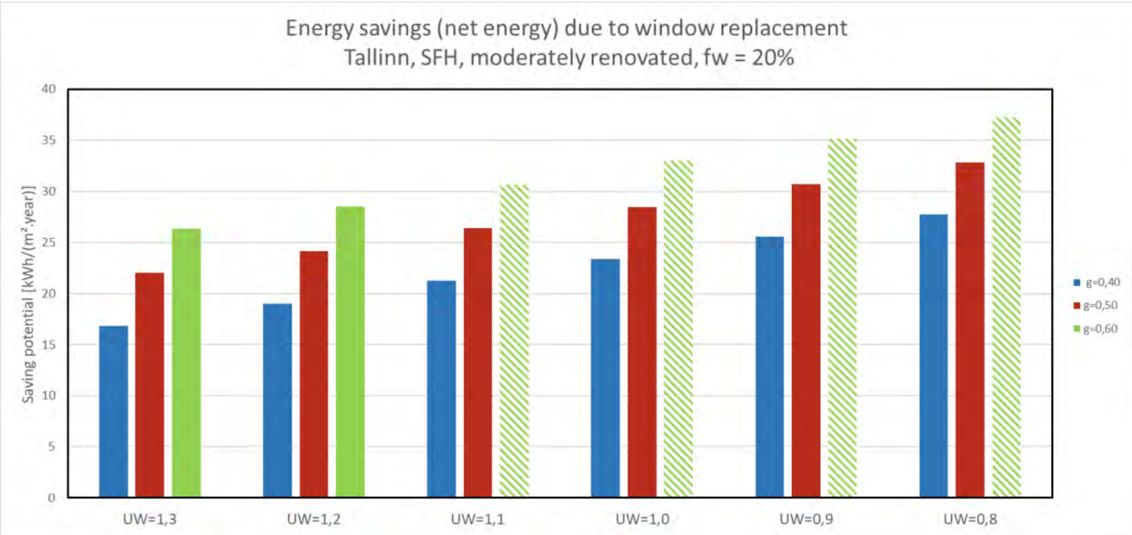


Figure D-44: Net energy savings for SFH, base case 2

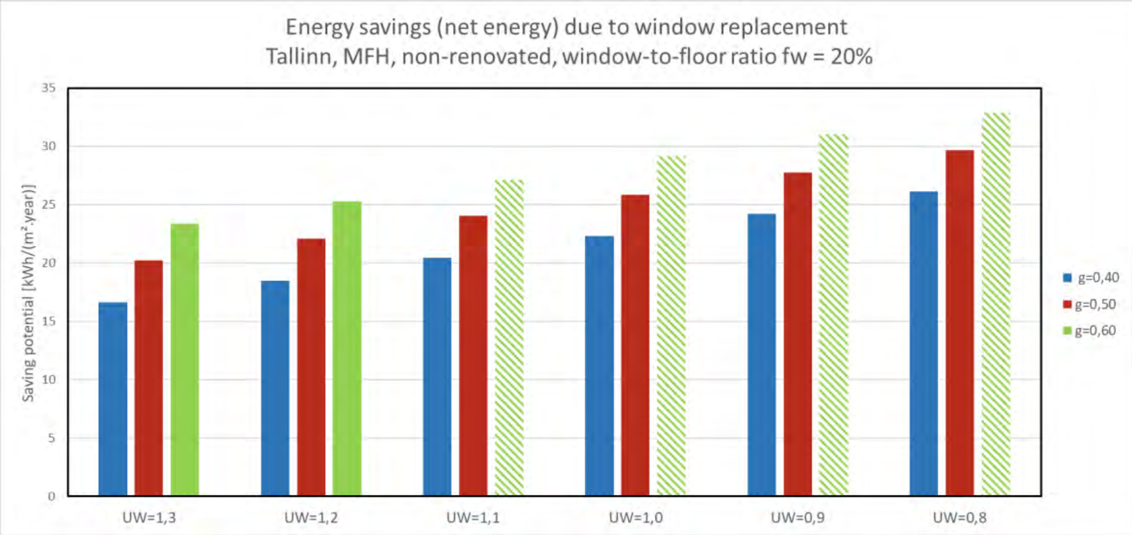


Figure D-45: Net energy savings for MFH, base case 1

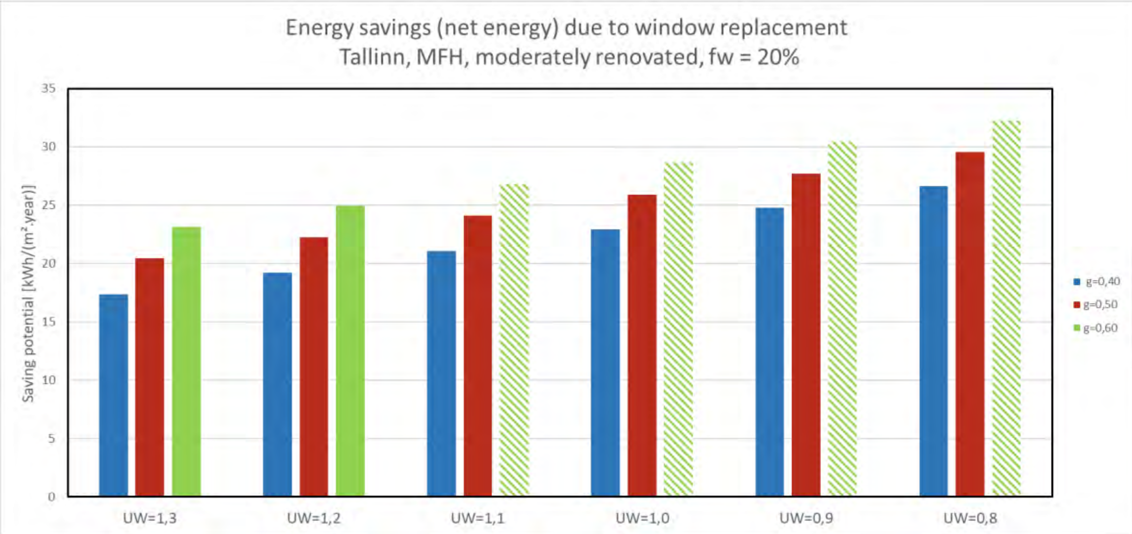


Figure D-46: Net energy savings for MFH, base case 2

D 8.2 Results national level (final energy and CO_2-savings)

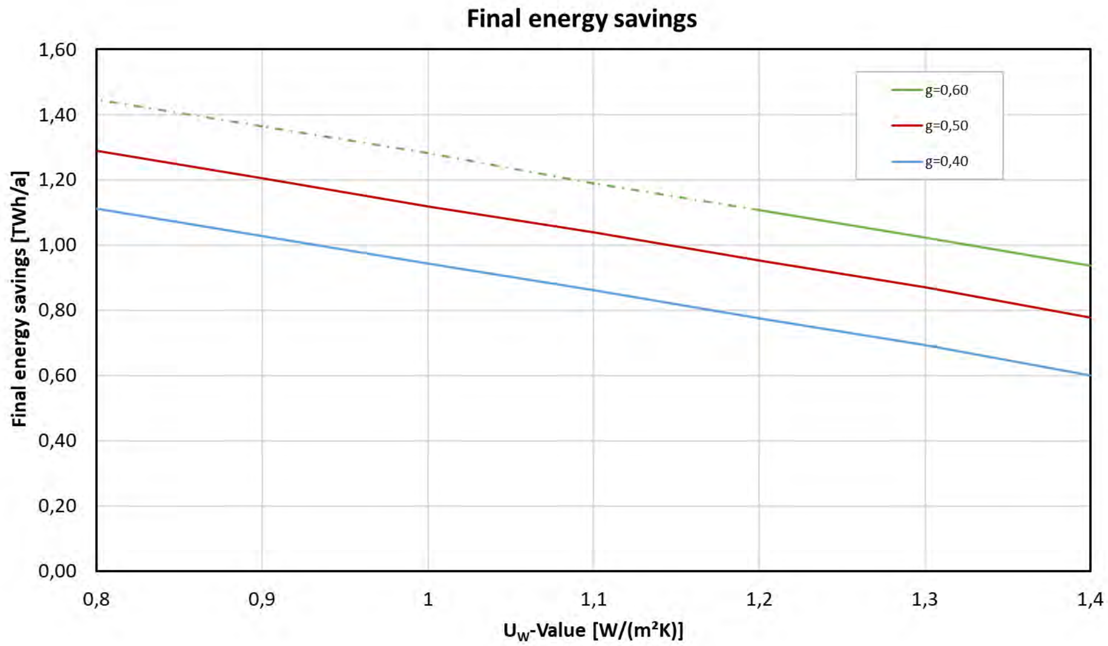


Figure D-47: Final energy savings Estonia

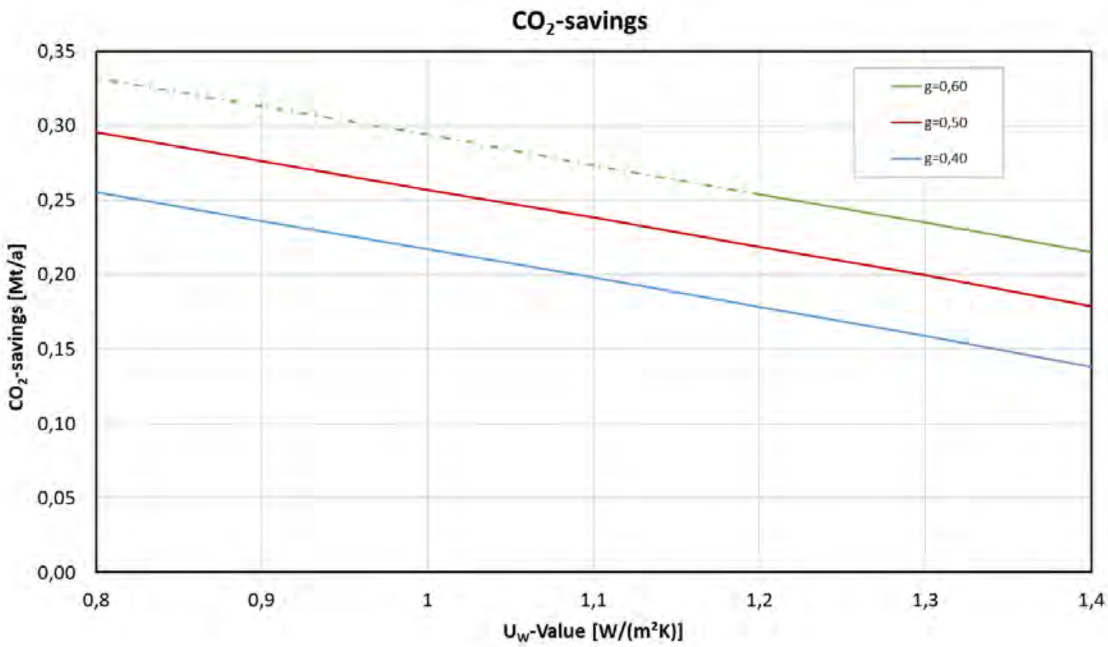


Figure D-48: CO_2-emission savings Estonia

D 9 Finland

D 9.1 Results building level (net energy)

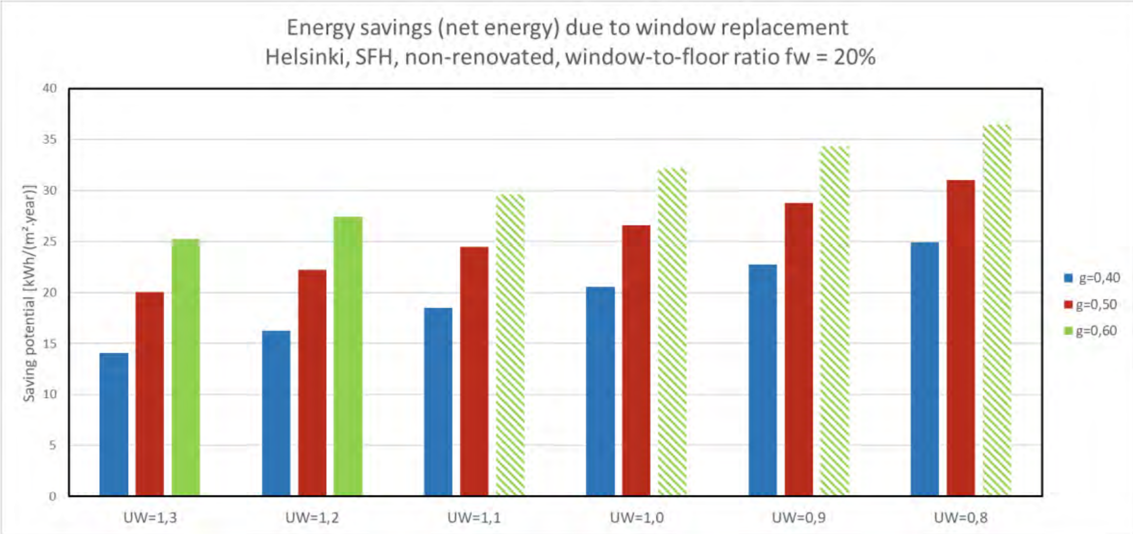


Figure D-49: Net energy savings for SFH, base case 1

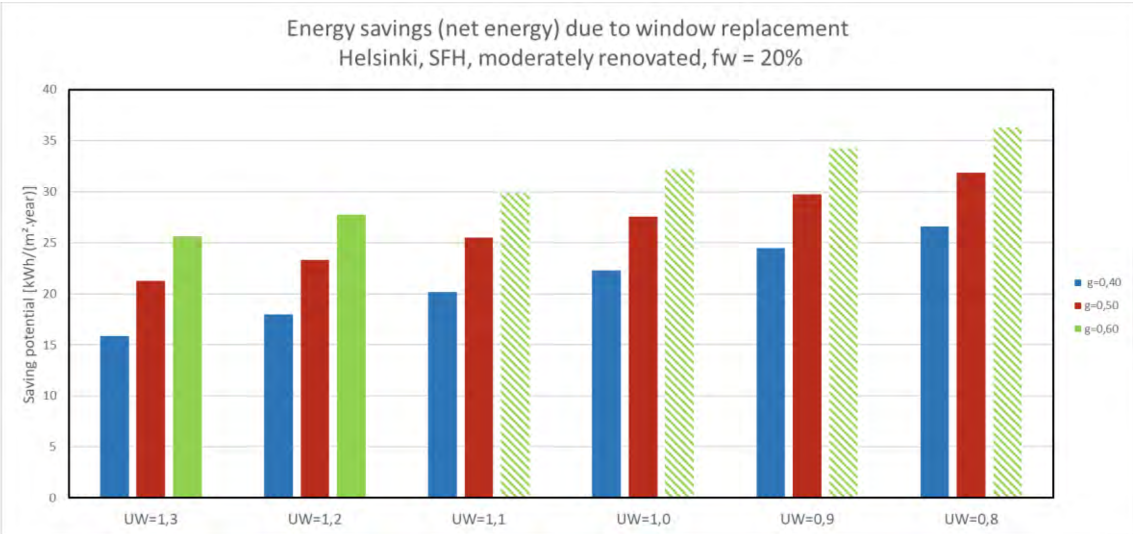


Figure D-50: Net energy savings for SFH, base case 2

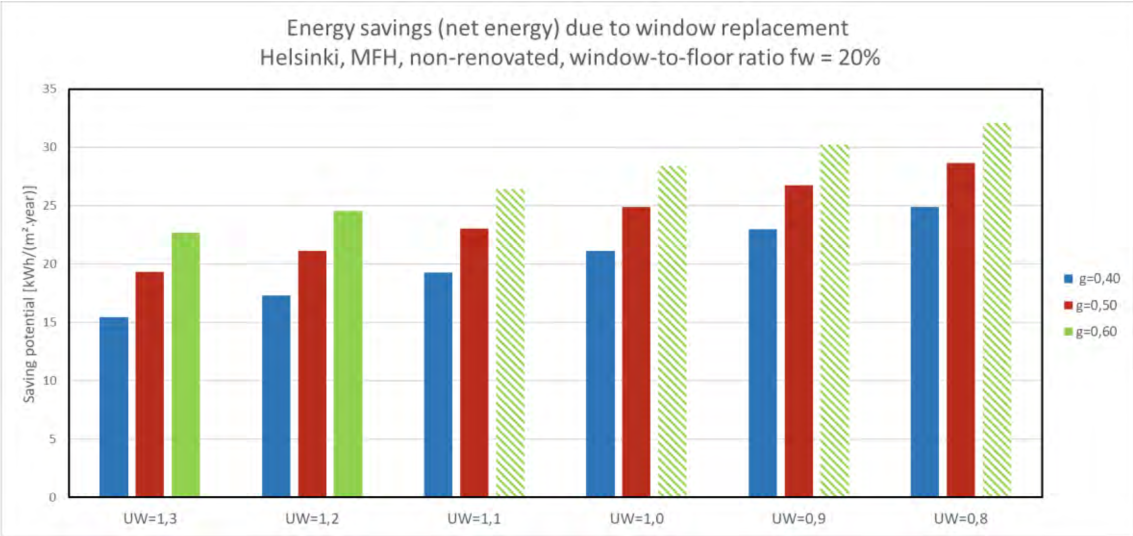


Figure D-51: Net energy savings for MFH, base case 1

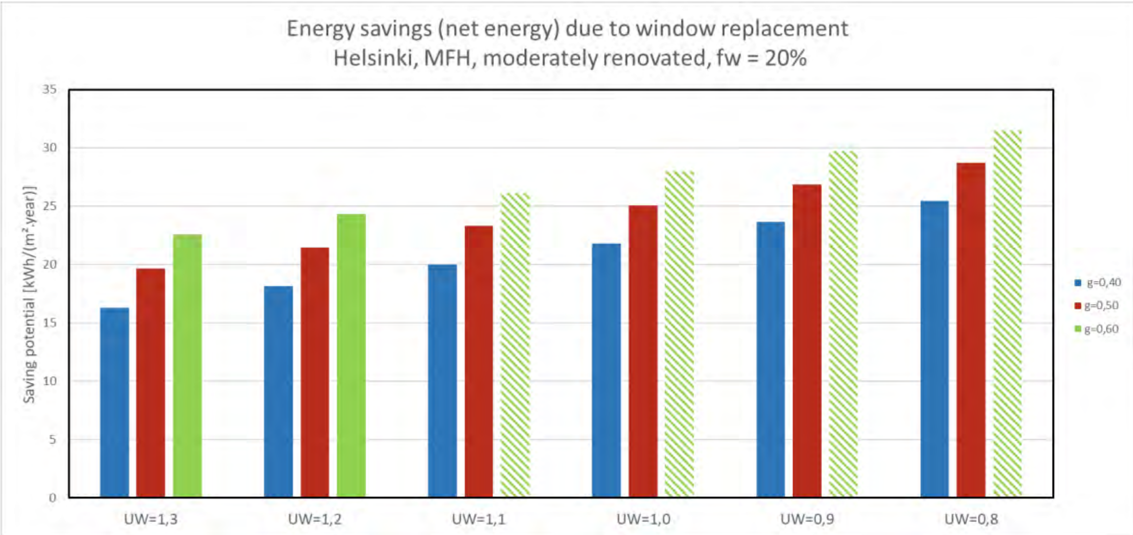


Figure D-52: Net energy savings for MFH, base case 2

D 9.2 Results national level (final energy and CO_2-savings)

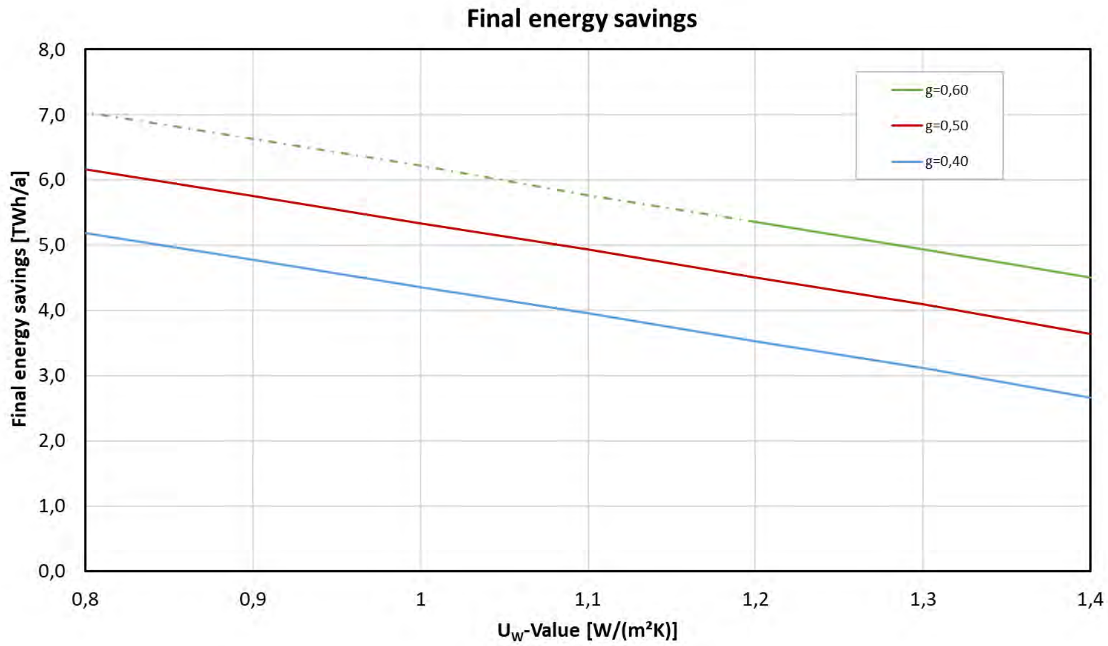


Figure D-53: Final energy savings Finland

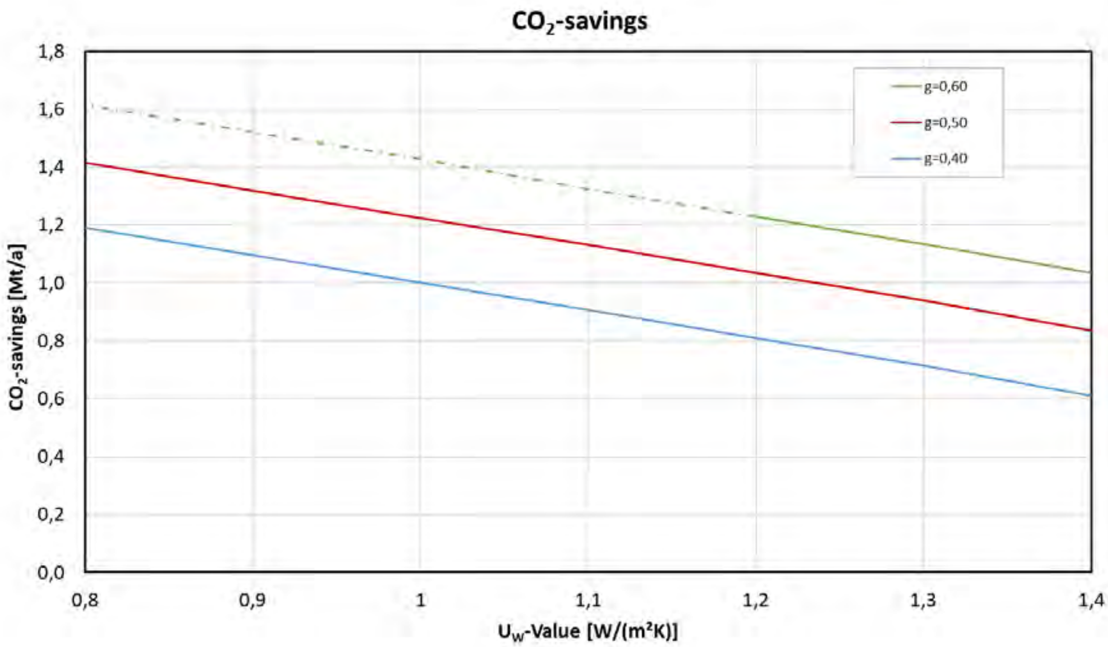


Figure D-54: CO_2-emission savings Finland

D 10 France

D 10.1 Results building level (net energy)

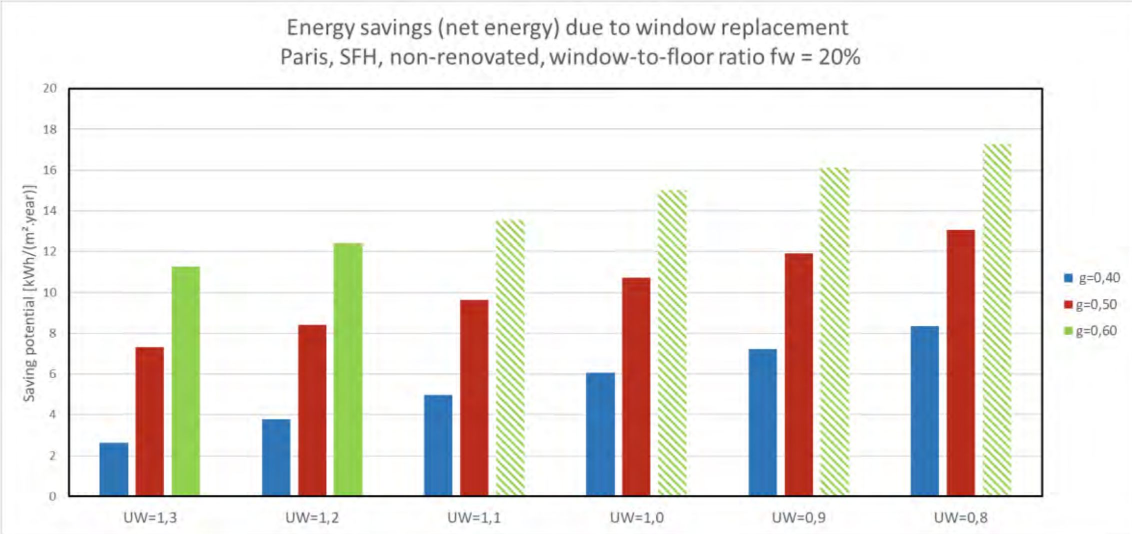


Figure D-55: Net energy savings for SFH, base case 1

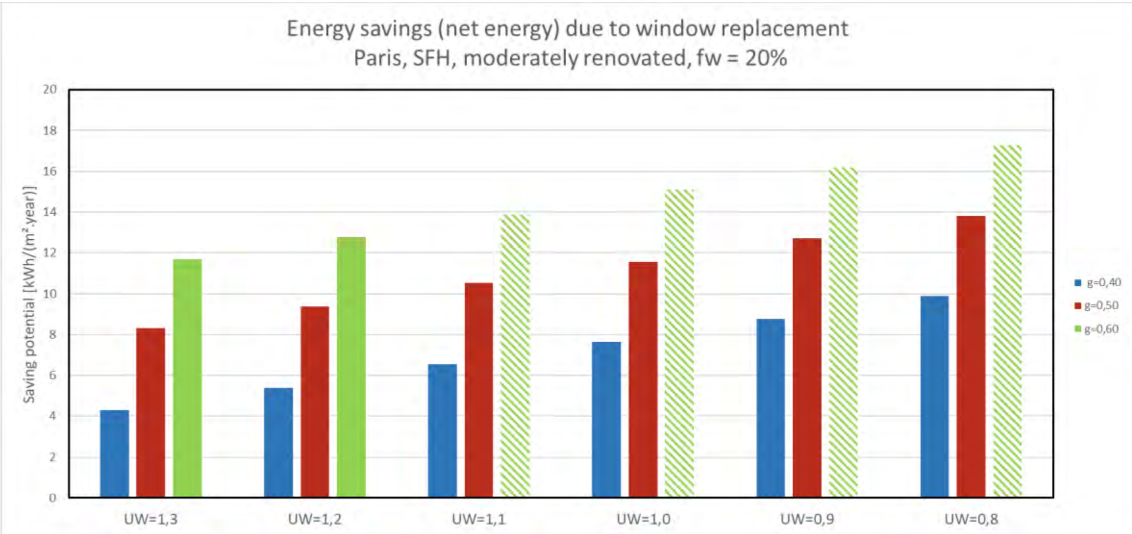


Figure D-56: Net energy savings for SFH, base case 2

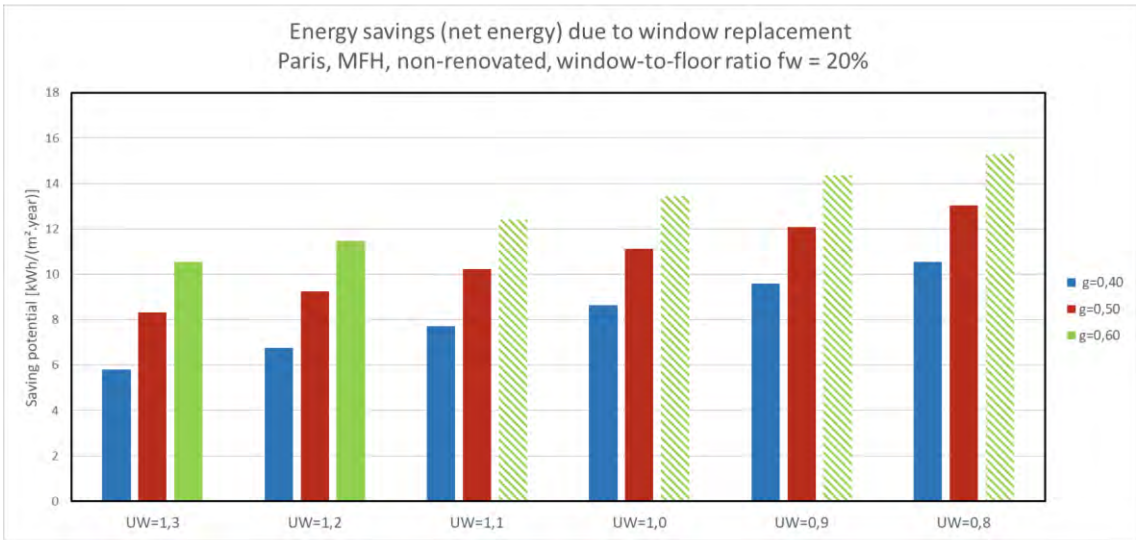


Figure D-57: Net energy savings for MFH, base case 1

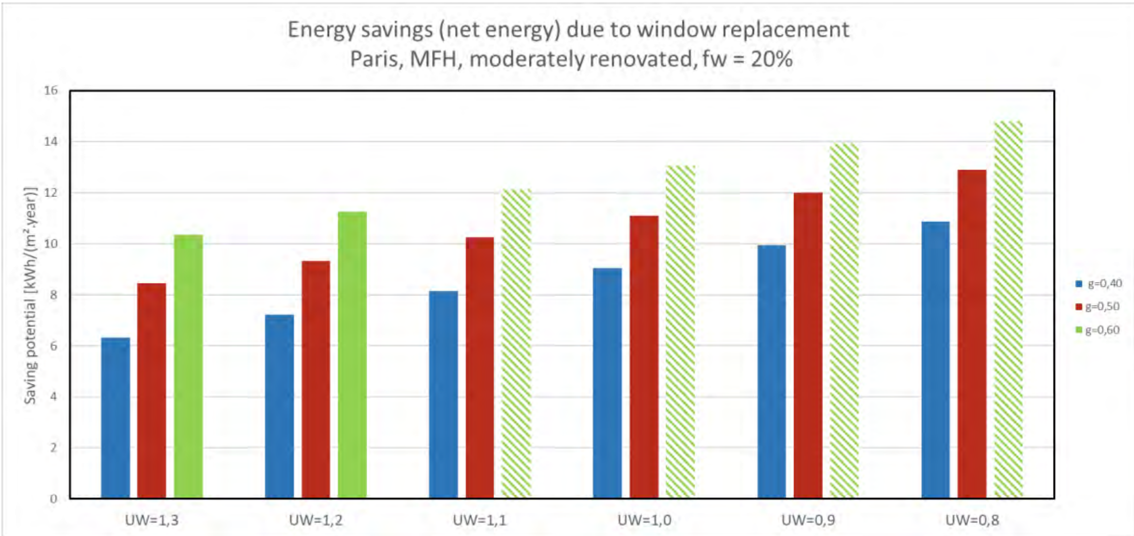


Figure D-58: Net energy savings for MFH, base case 2

D 10.2 Results national level (final energy and CO_2-savings)

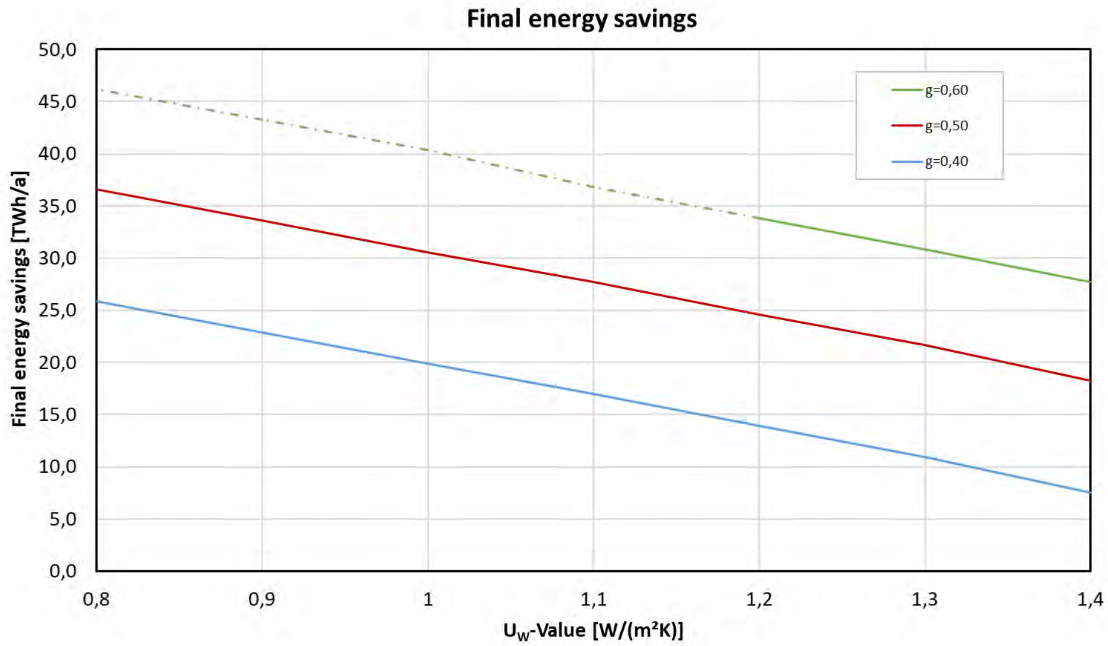
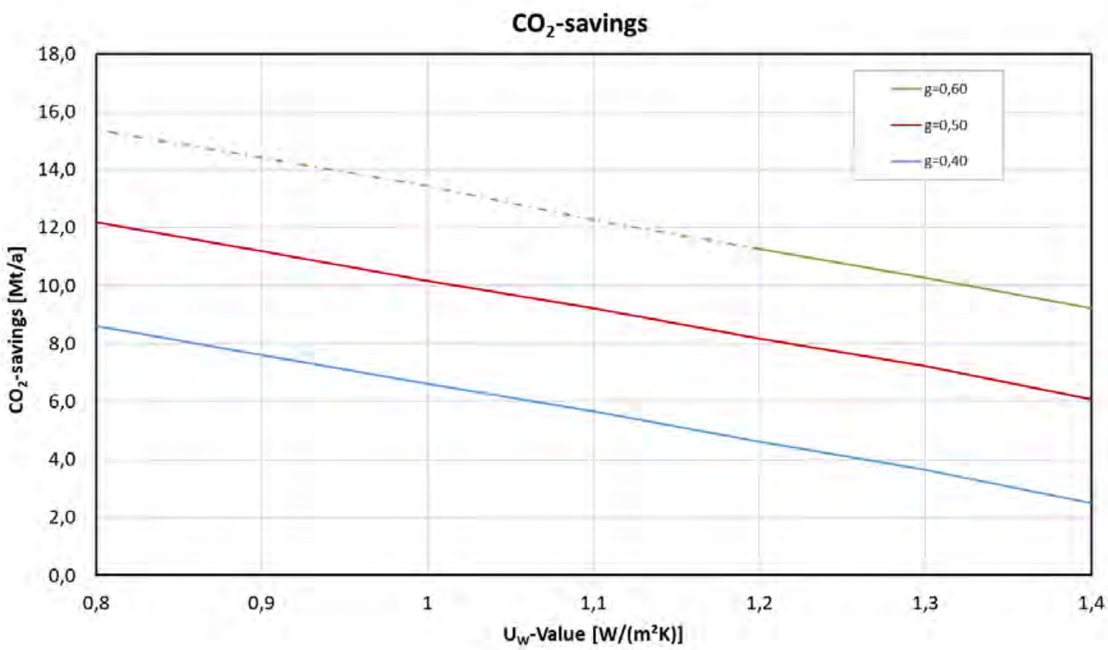


Figure D-59: Final energy savings France

Figure D-60: C



O_2-emission savings France

D 11 Germany

D 11.1 Results building level (net energy)

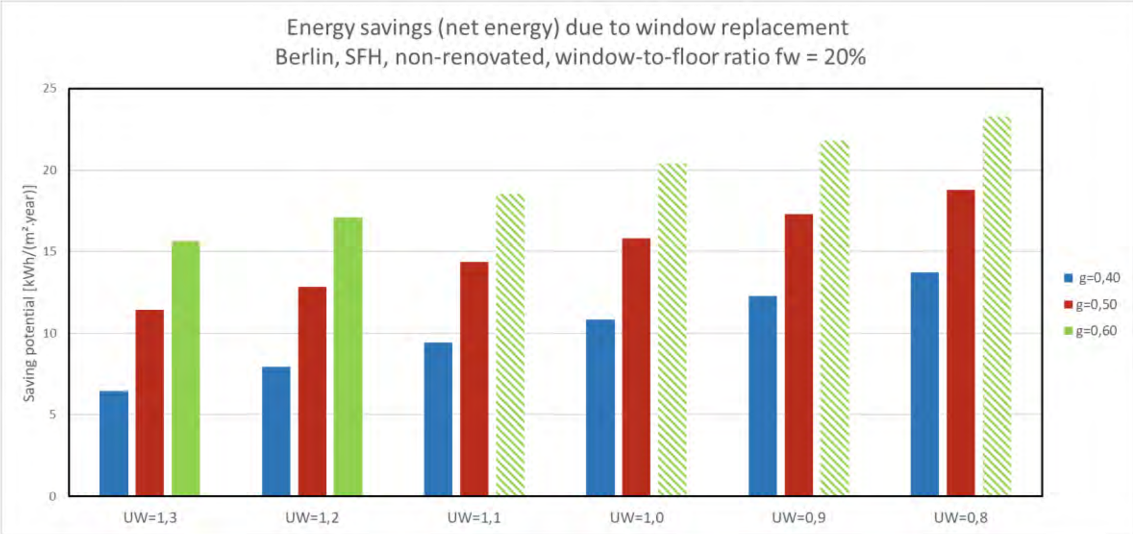


Figure D-61: Net energy savings for SFH, base case 1

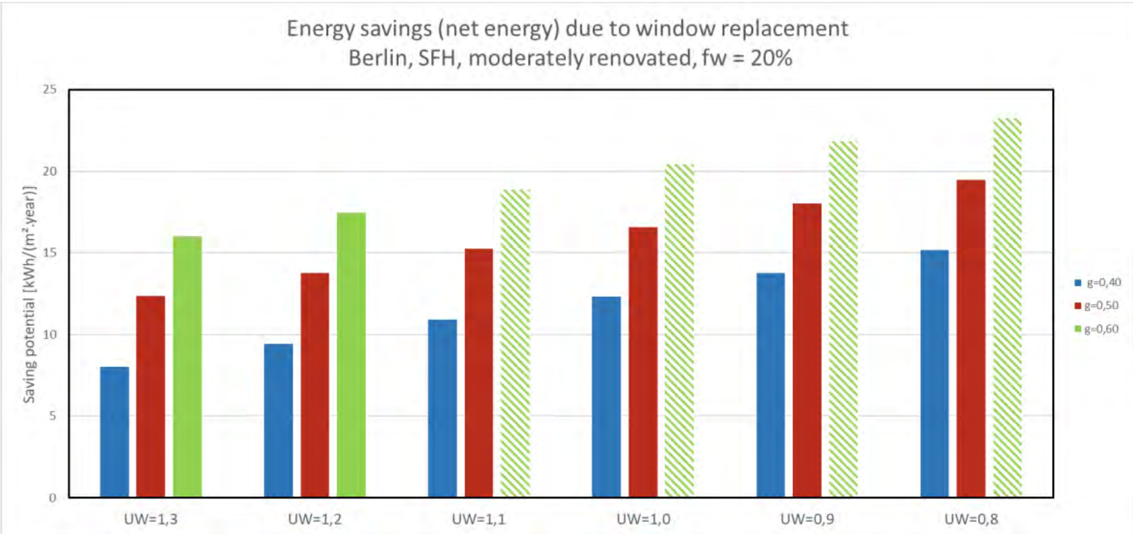


Figure D-62: Net energy savings for SFH, base case 2

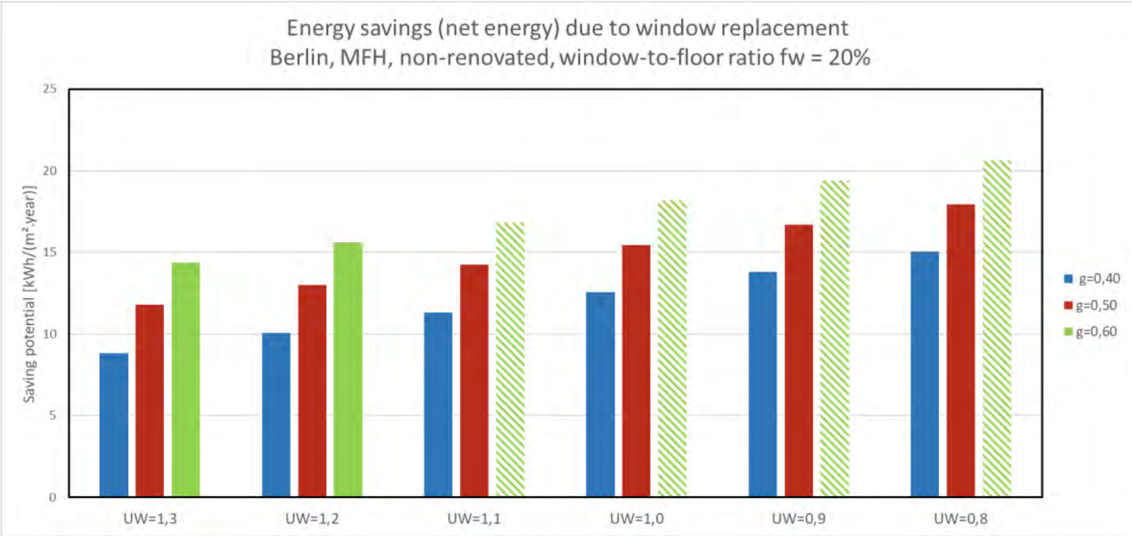


Figure D-63: Net energy savings for MFH, base case 1

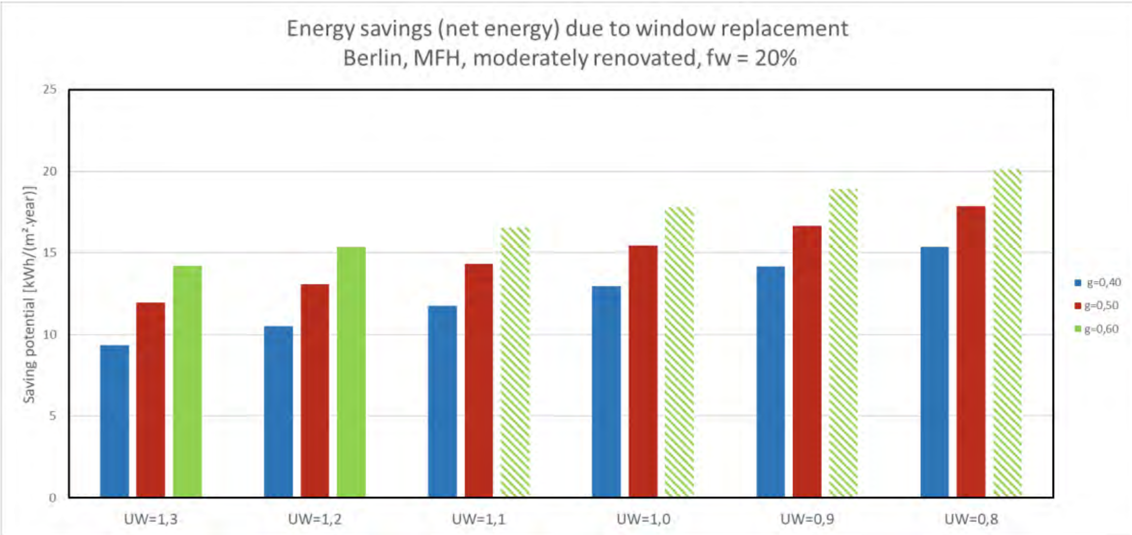


Figure D-64: Net energy savings for MFH, base case 2

D 11.2 Results national level (final energy and CO_2-savings)

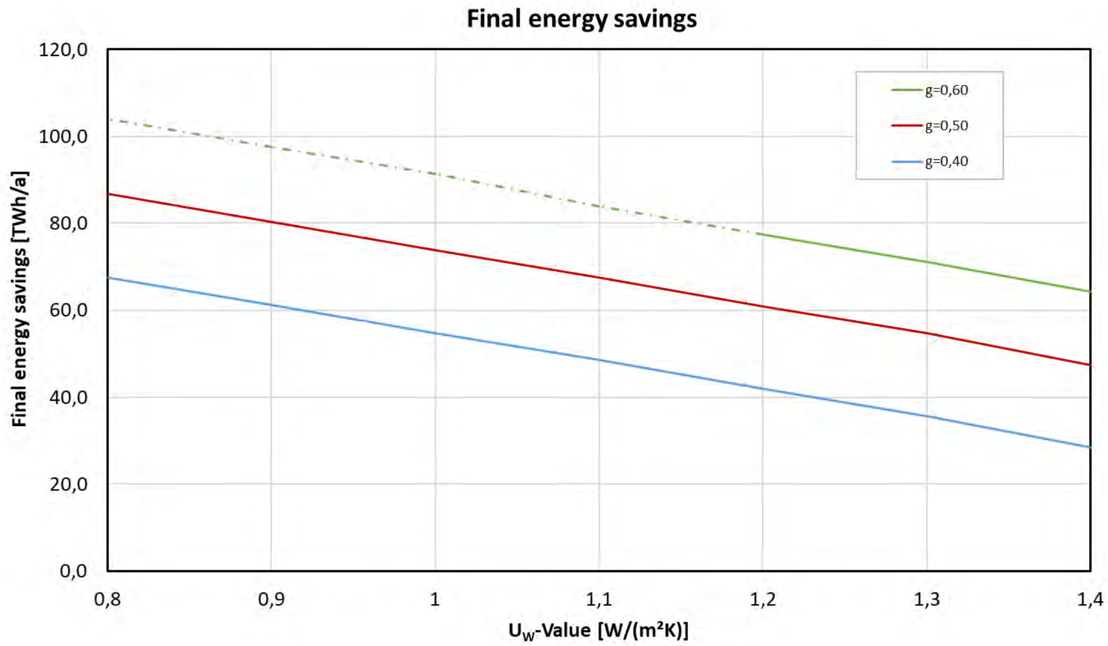


Figure D-65: Final energy savings Germany

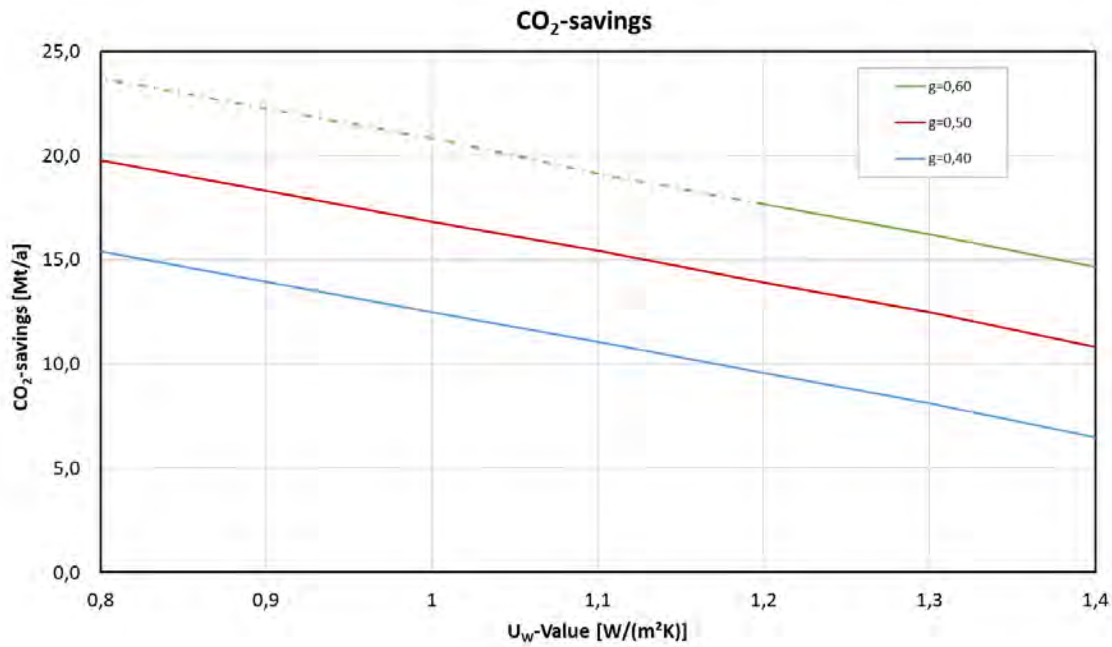


Figure D-66: CO_2-emission savings Germany

D 12 Greece

D 12.1 Results building level (net energy)

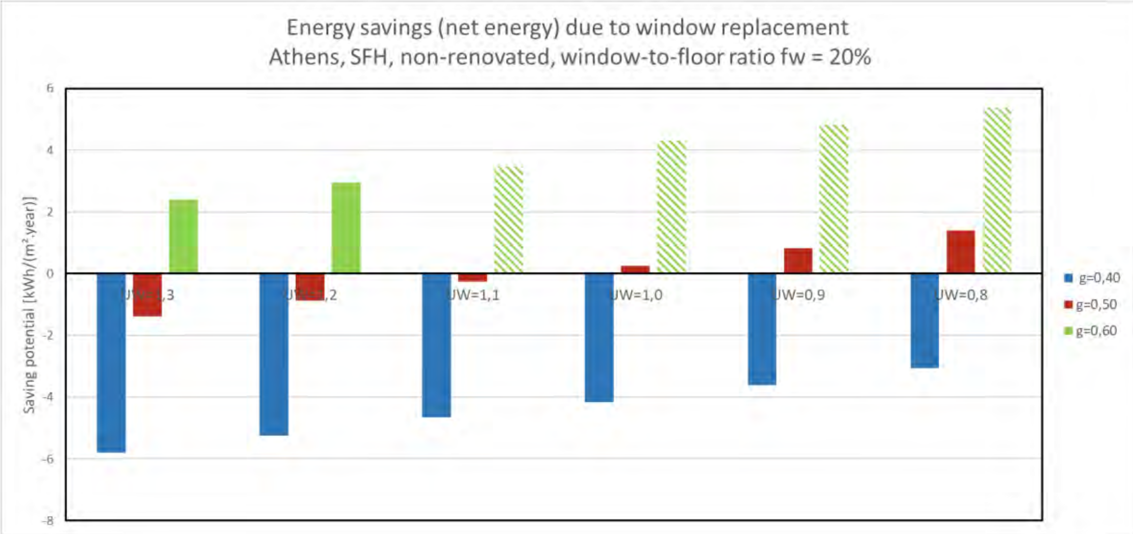


Figure D-67: Net energy savings for SFH, base case 1

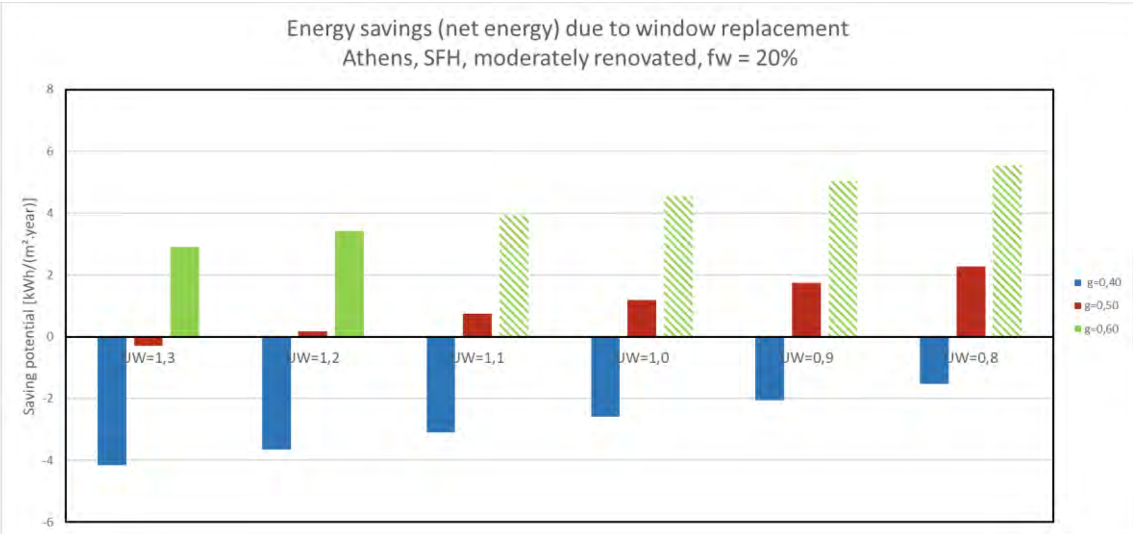


Figure D-68: Net energy savings for SFH, base case 2

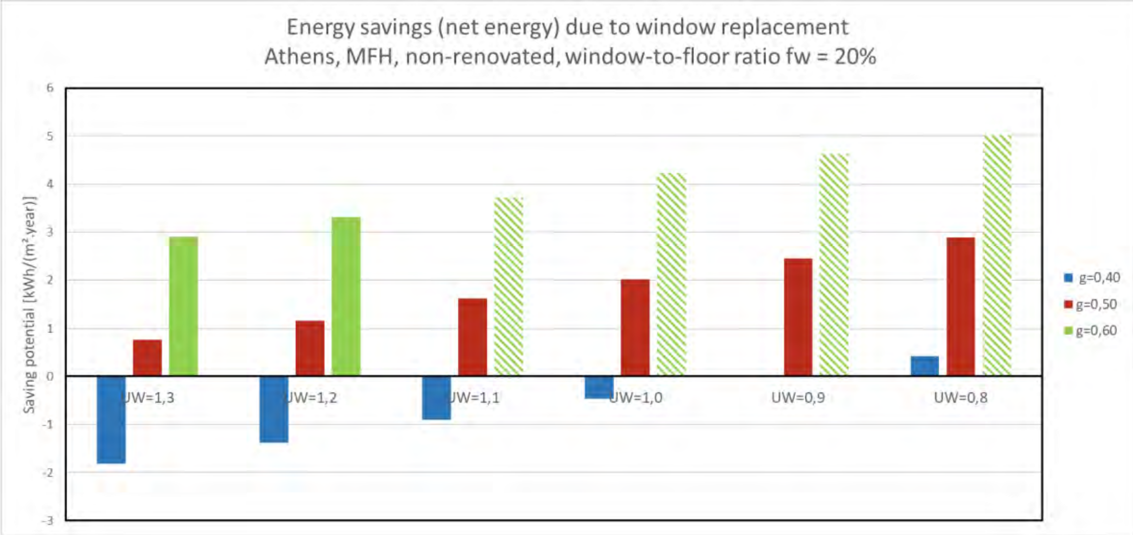


Figure D-69: Net energy savings for MFH, base case 1

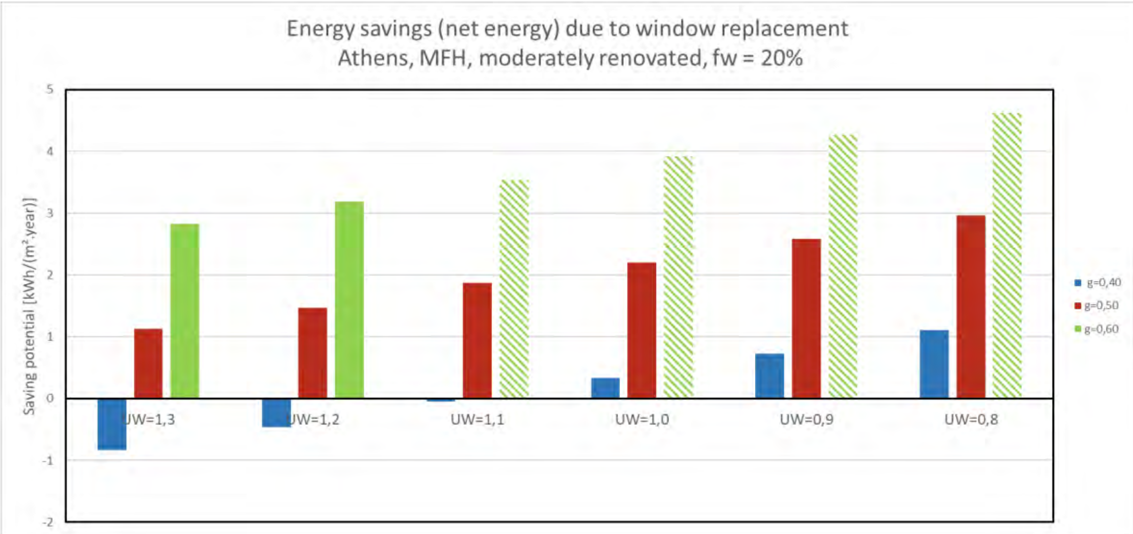


Figure D-70: Net energy savings for MFH, base case 2

D 12.2 Results national level (final energy and CO_2-savings)

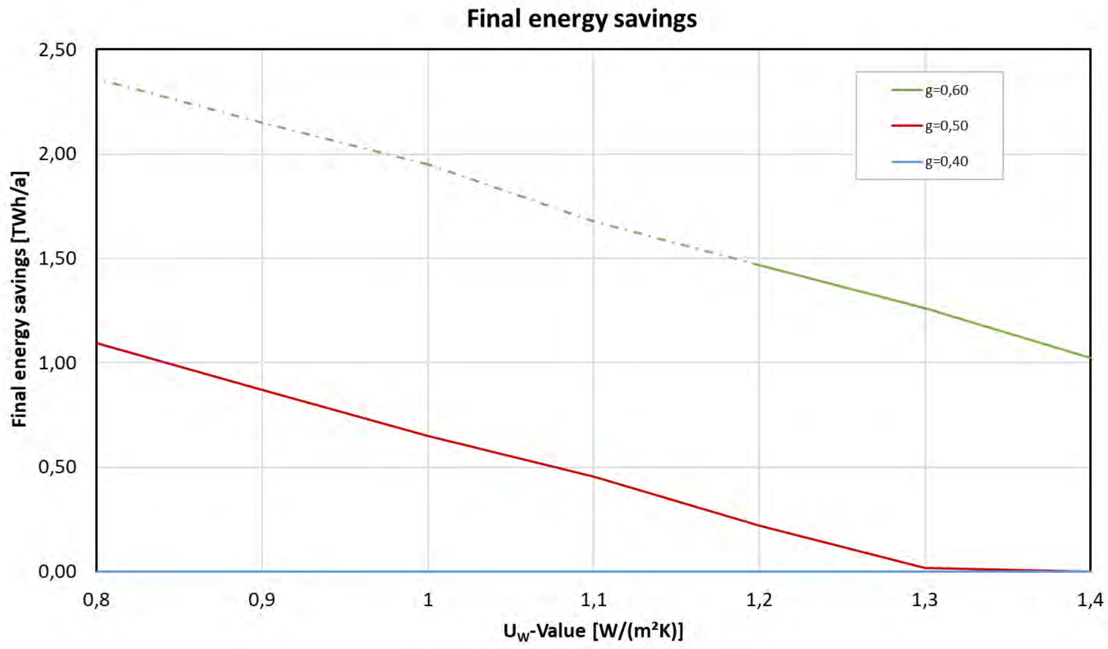


Figure D-71: Final energy savings Greece

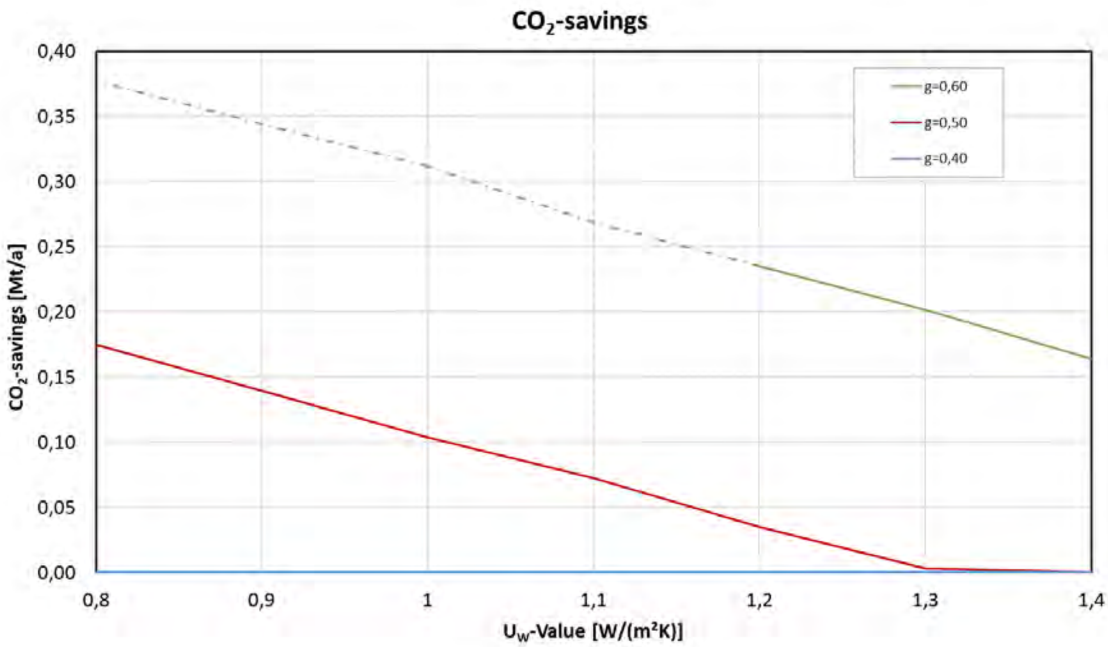


Figure D-72: CO_2-emission savings Greece

D 13 Hungary

D 13.1 Results building level (net energy)

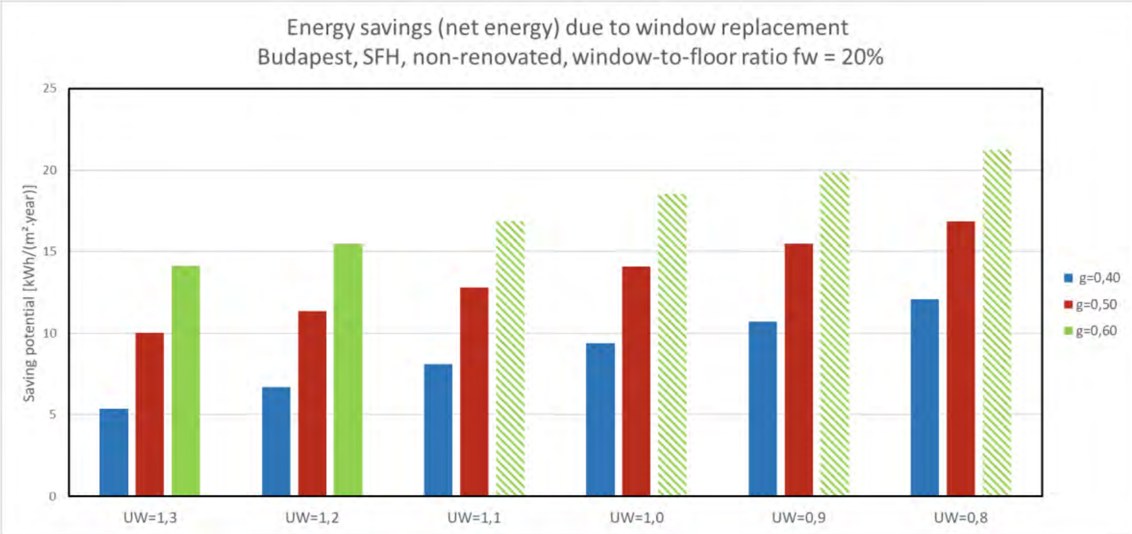


Figure D-73: Net energy savings for SFH, base case 1

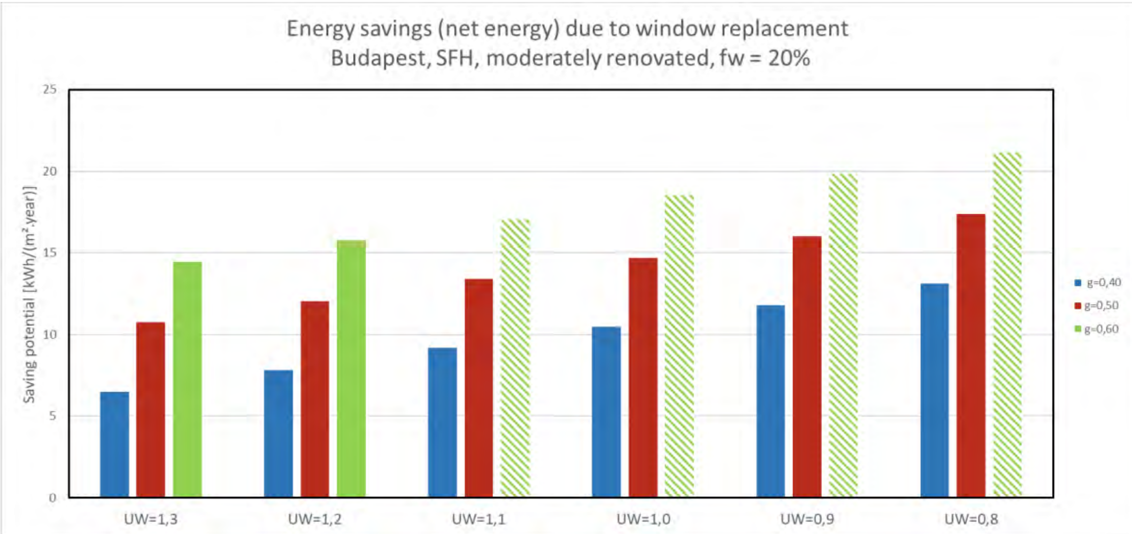


Figure D-74: Net energy savings for SFH, base case 2

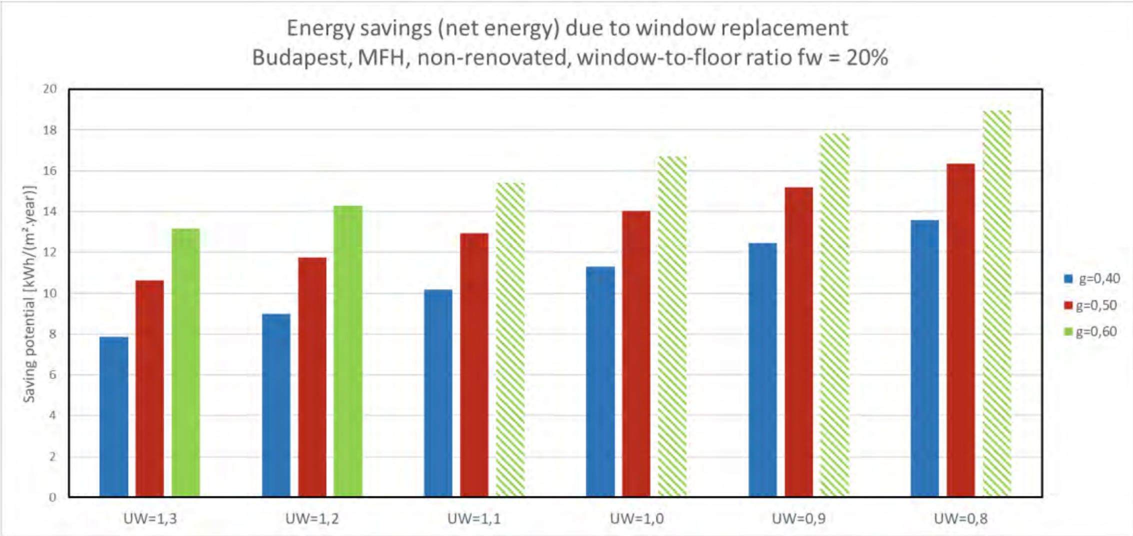


Figure D-75: Net energy savings for MFH, base case 1

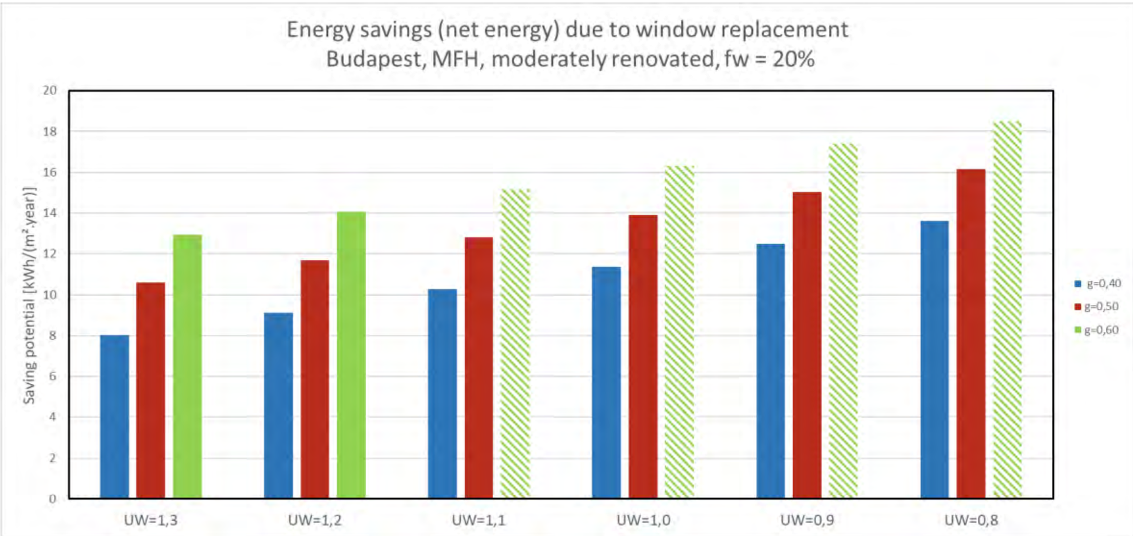


Figure D-76: Net energy savings for MFH, base case 2

D 13.2 Results national level (final energy and CO_2-savings)

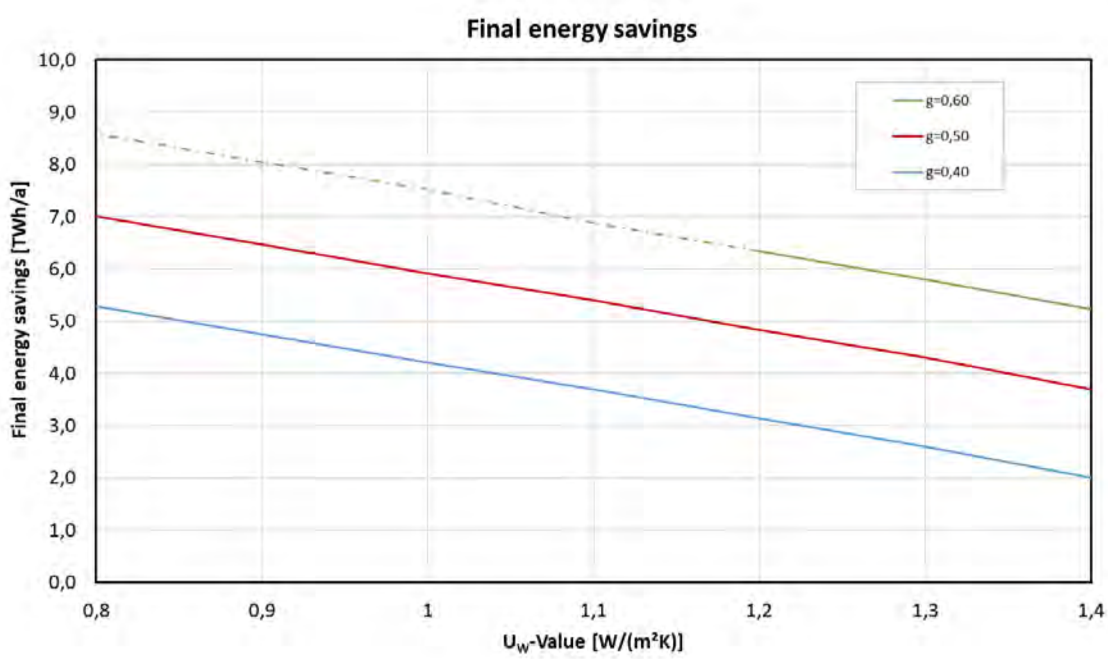


Figure D-77: Final energy savings Hungary

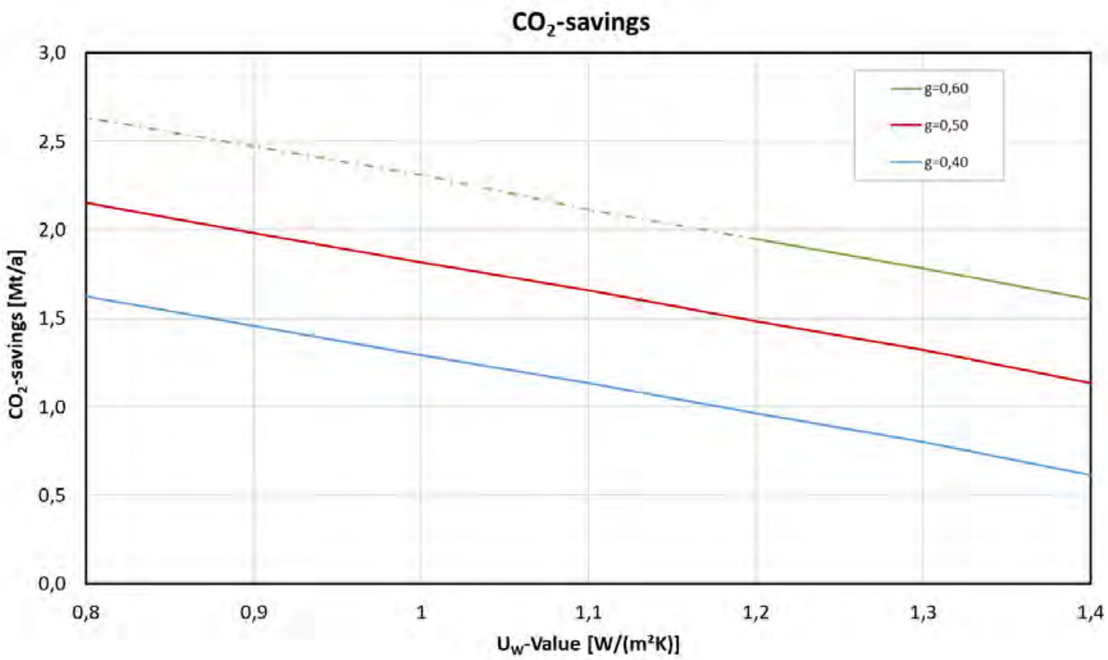


Figure D-78: CO_2-emission savings Hungary

D 14 Ireland

D 14.1 Results building level (net energy)

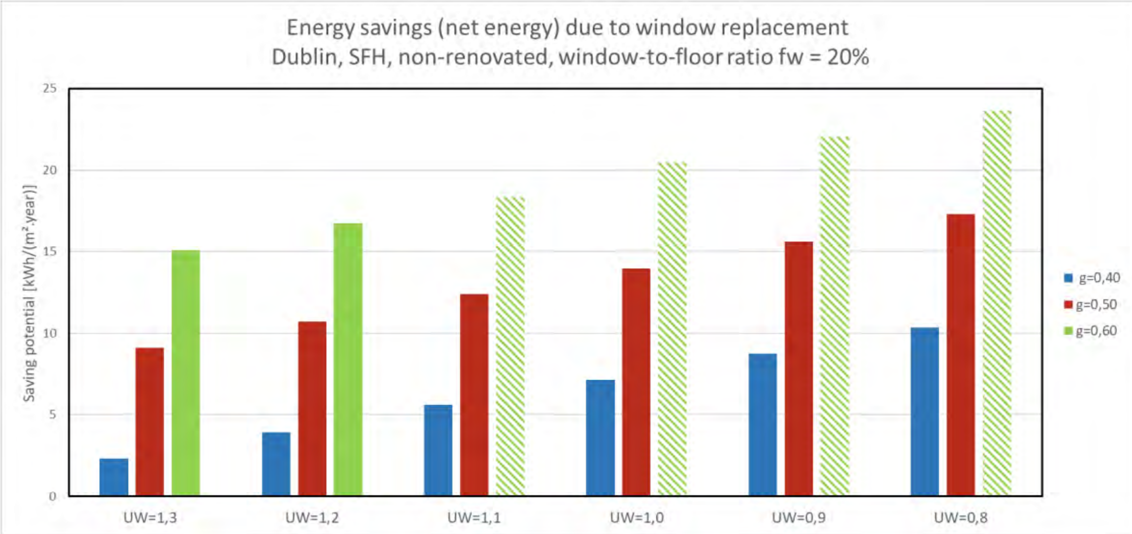


Figure D-79: Net energy savings for SFH, base case 1

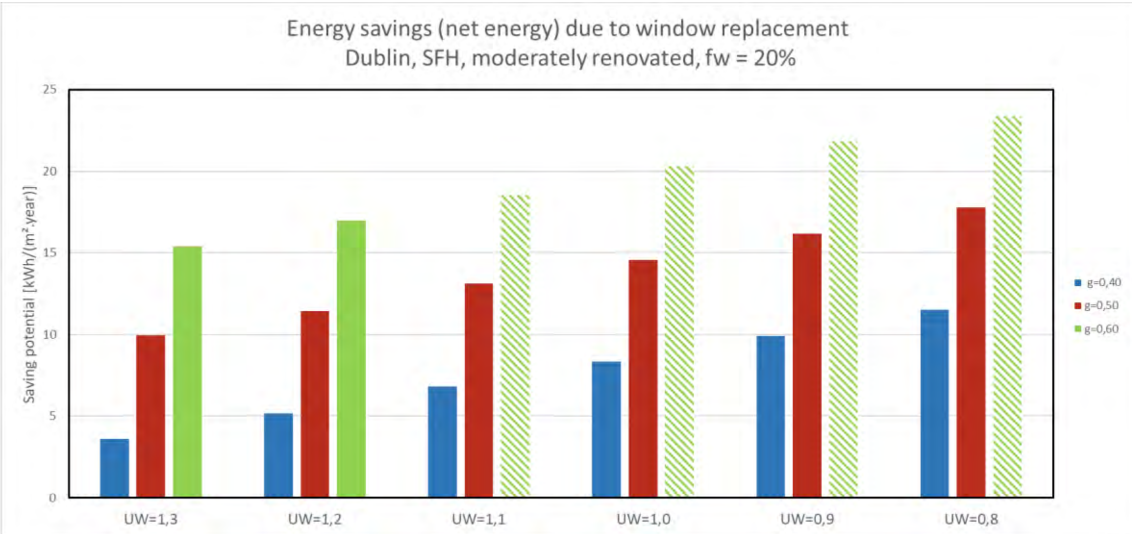


Figure D-80: Net energy savings for SFH, base case 2

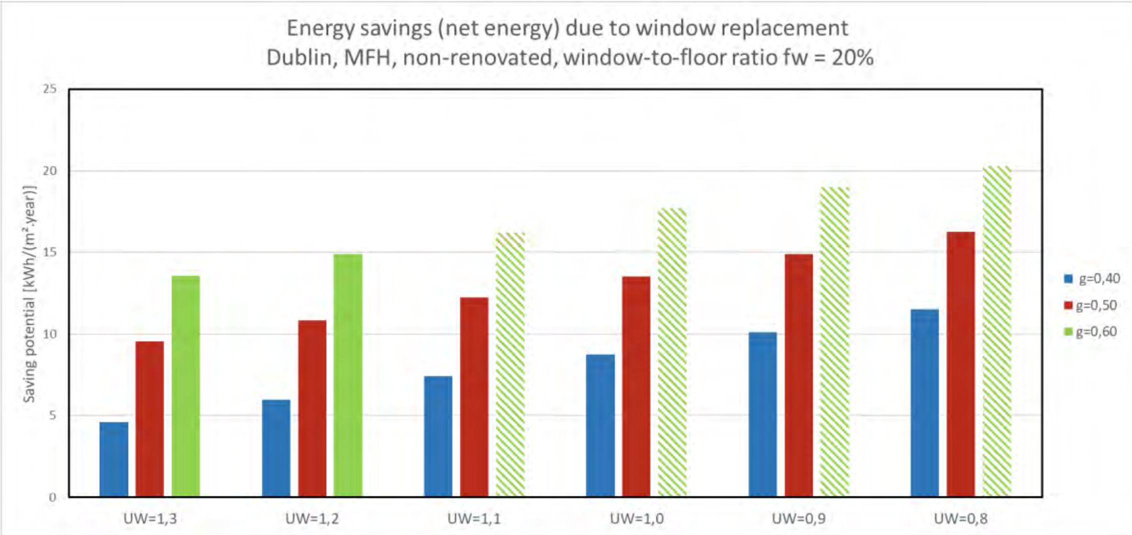


Figure D-81: Net energy savings for MFH, base case 1

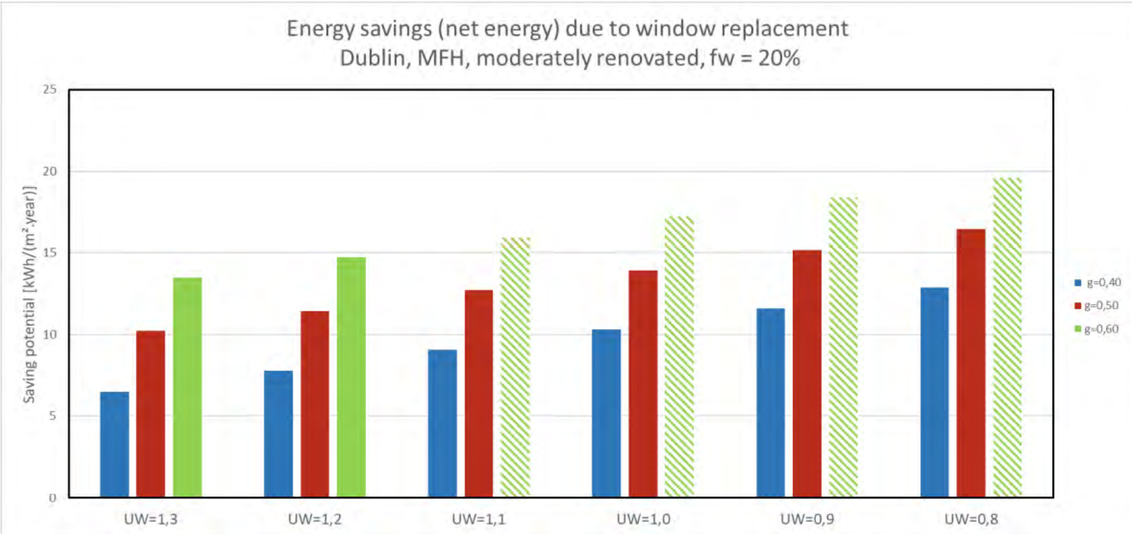


Figure D-82: Net energy savings for MFH, base case 2

D 14.2 Results national level (final energy and CO_2-savings)

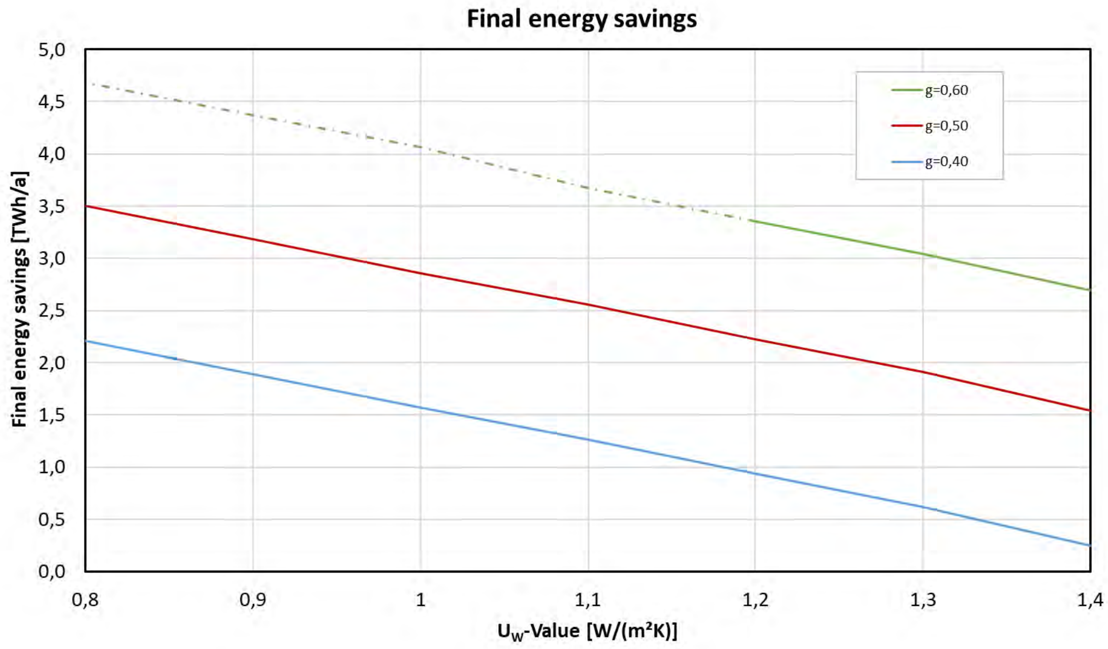


Figure D-83: Final energy savings Ireland

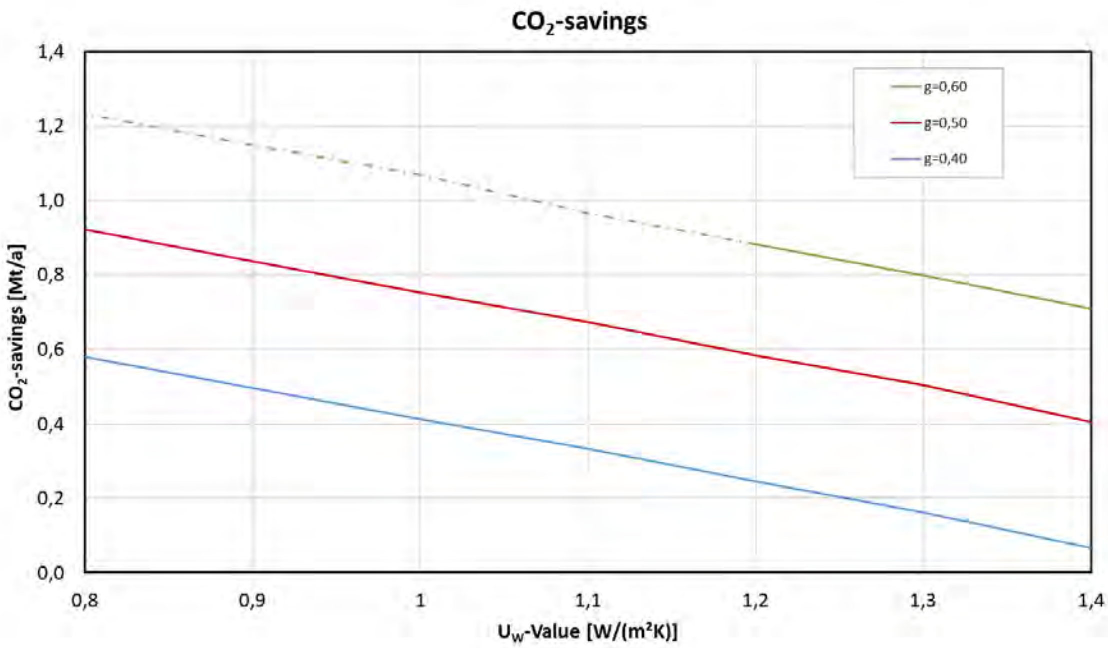


Figure D-84: CO_2-emission savings Ireland

D 15 Italy

D 15.1 Results building level (net energy)

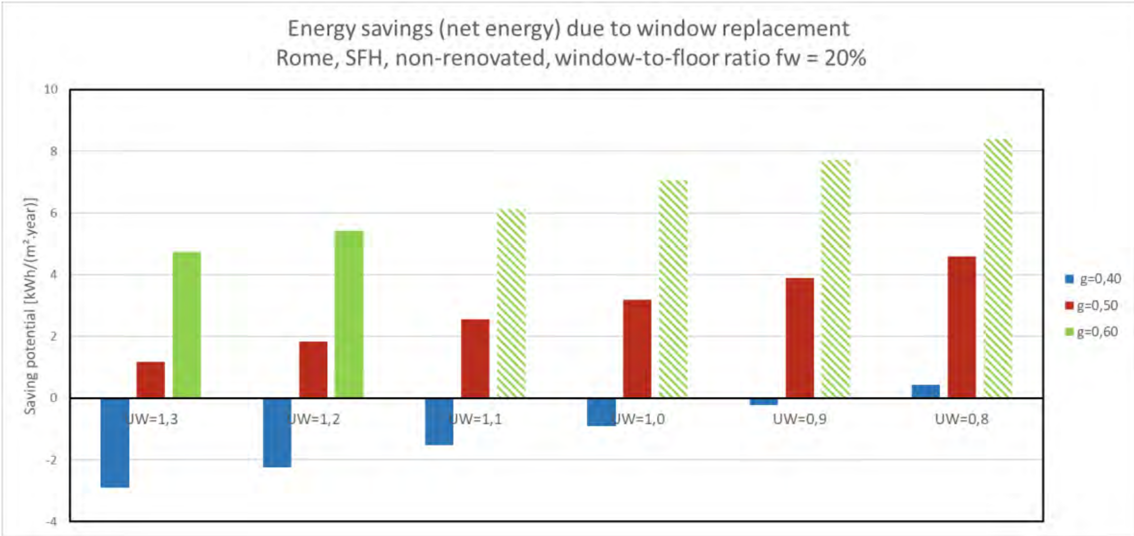


Figure D-85: Net energy savings for SFH, base case 1

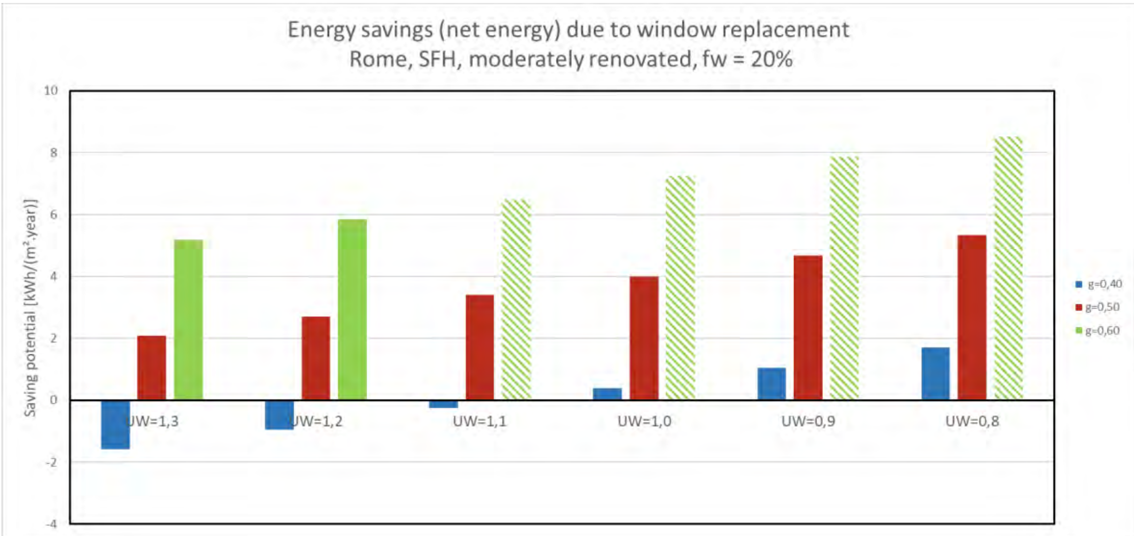
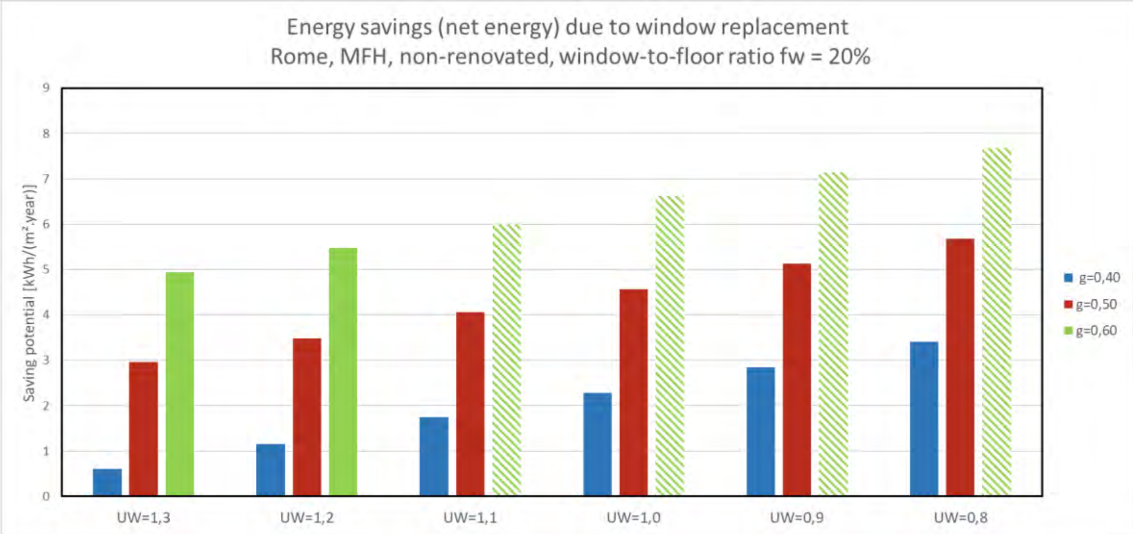


Figure D-86: Net energy savings for SFH, base case 2

Figure D-87: Net ener



gy savings for MFH, base case 1

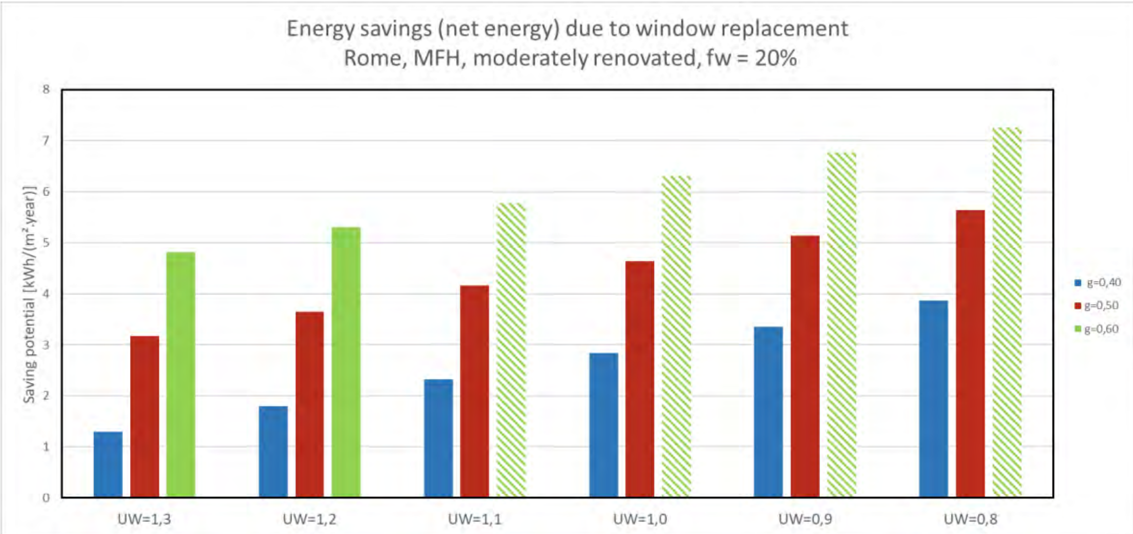


Figure D-88: Net energy savings for MFH, base case 2

D 15.2 Results national level (final energy and CO_2-savings)

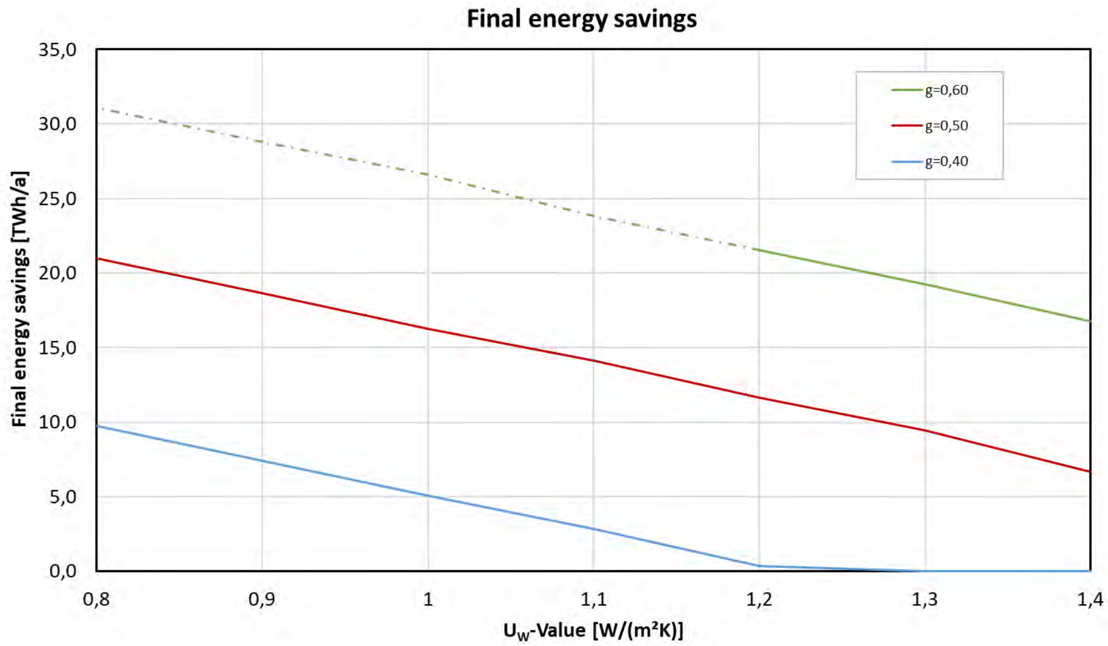


Figure D-89: Final energy savings Italy

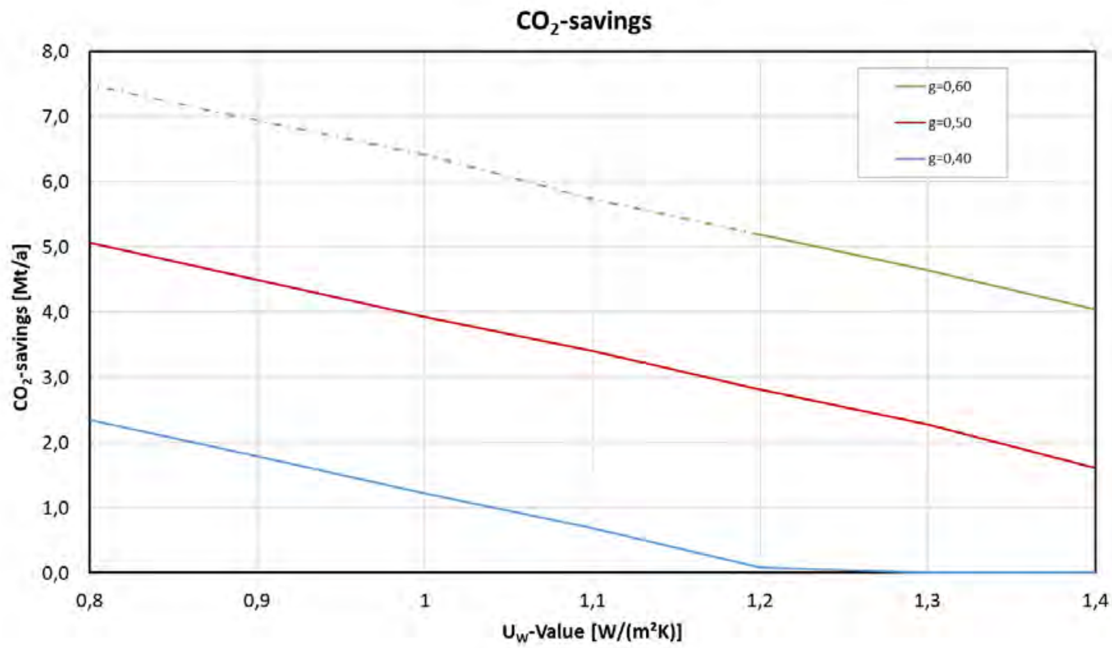


Figure D-90: CO_2-emission savings Italy

D 16 Latvia

D 16.1 Results building level (net energy)

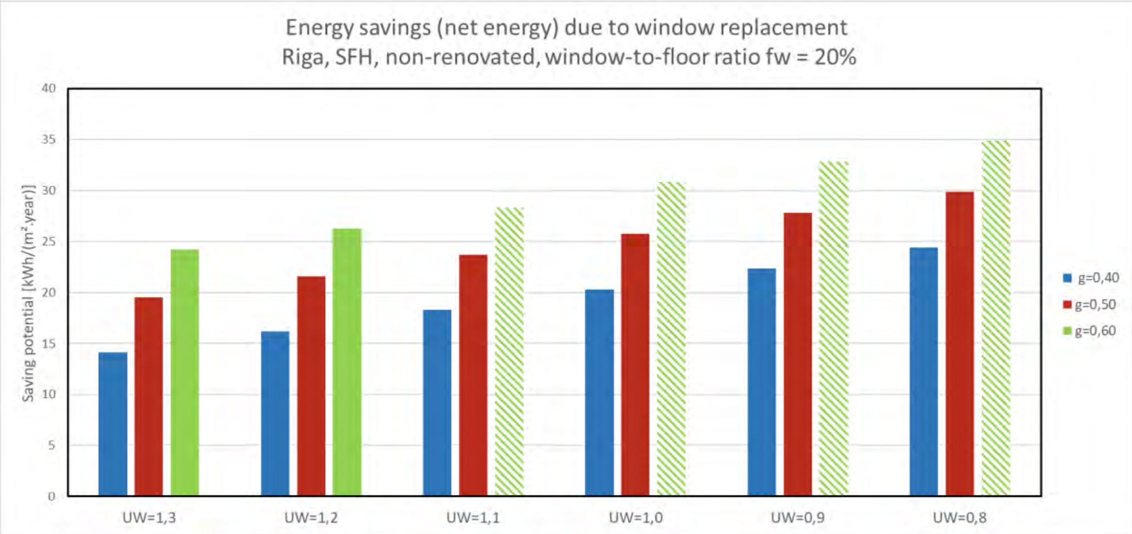


Figure D-91: Net energy savings for SFH, base case 1

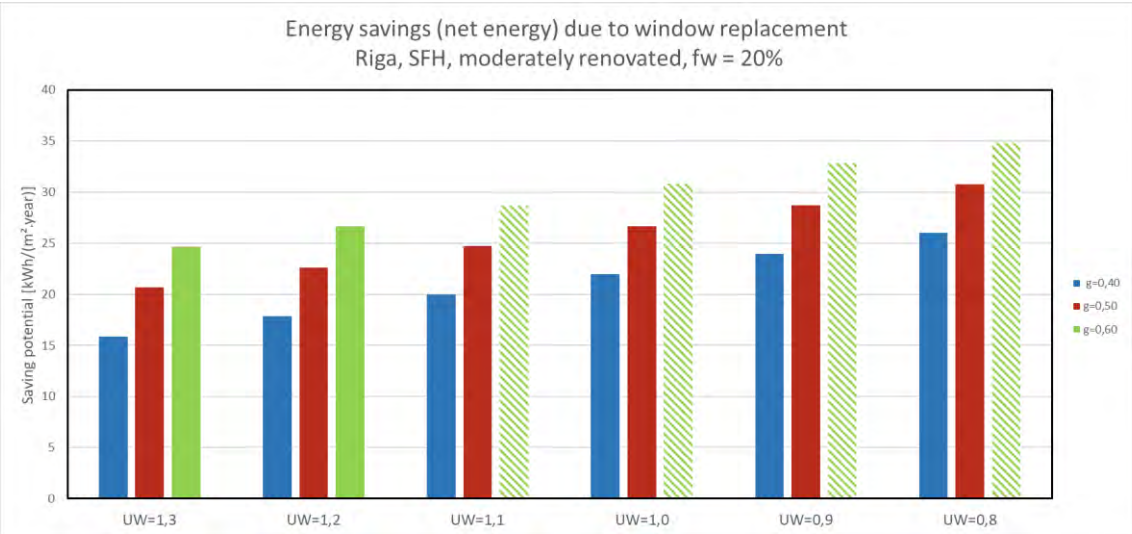


Figure D-92: Net energy savings for SFH, base case 2

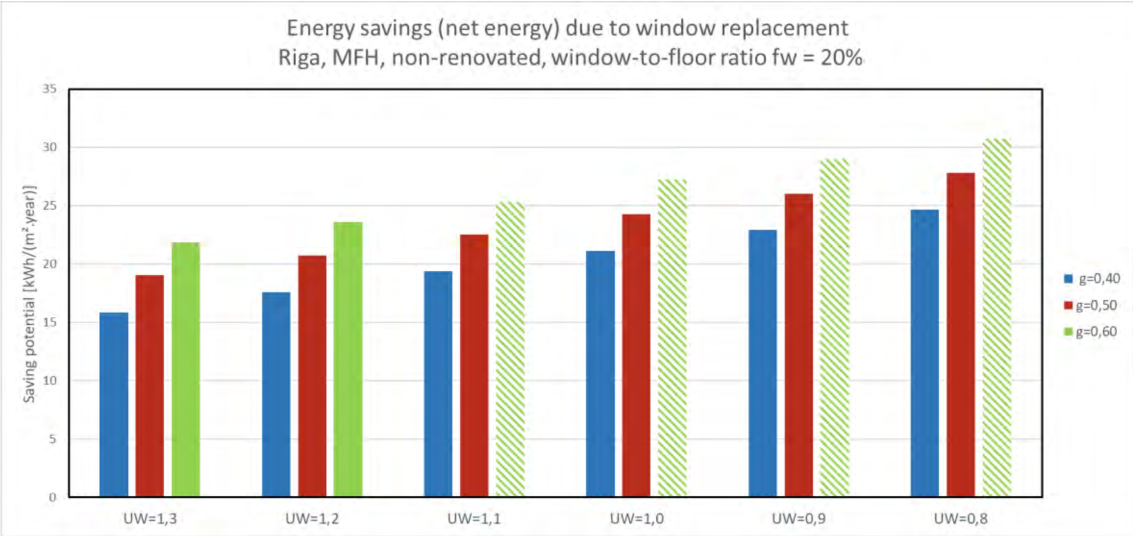


Figure D-93: Net energy savings for MFH, base case 1

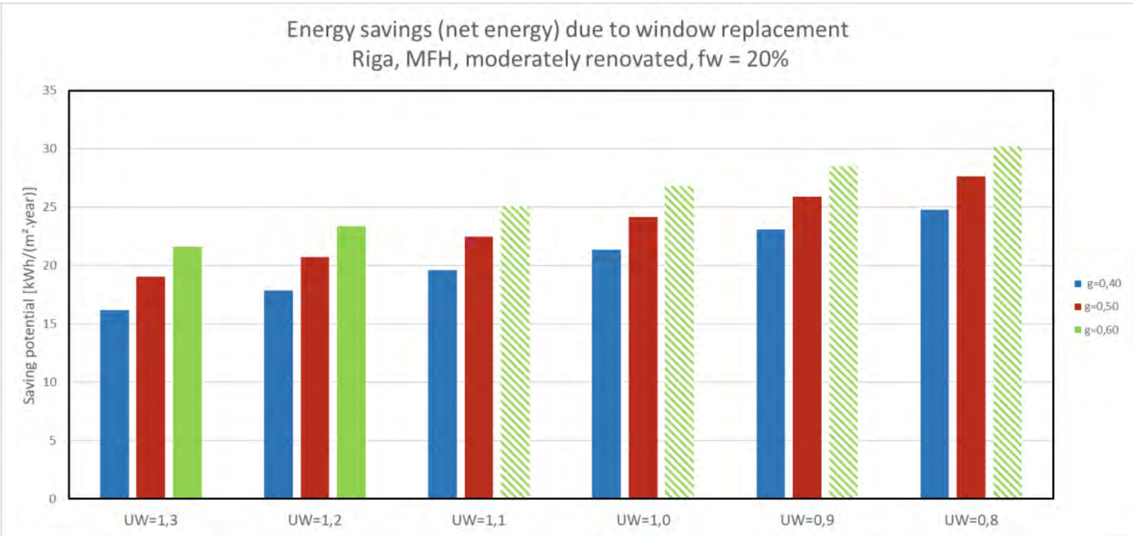


Figure D-94: Net energy savings for MFH, base case 2

D 16.2 Results national level (final energy and CO_2-savings)

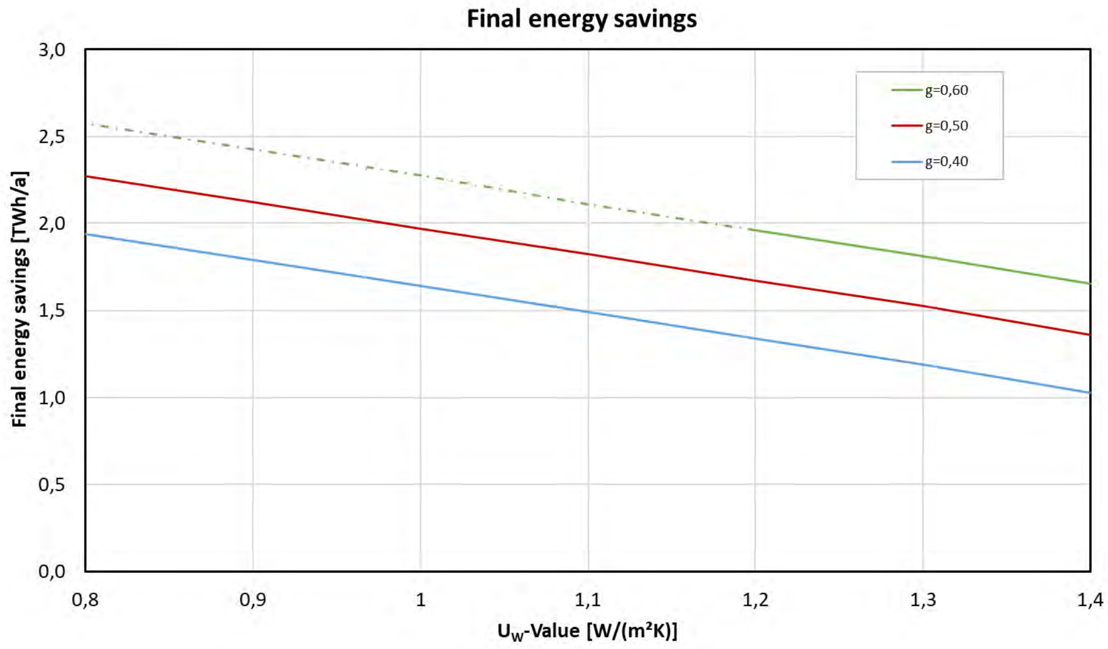


Figure D-95: Final energy savings Latvia

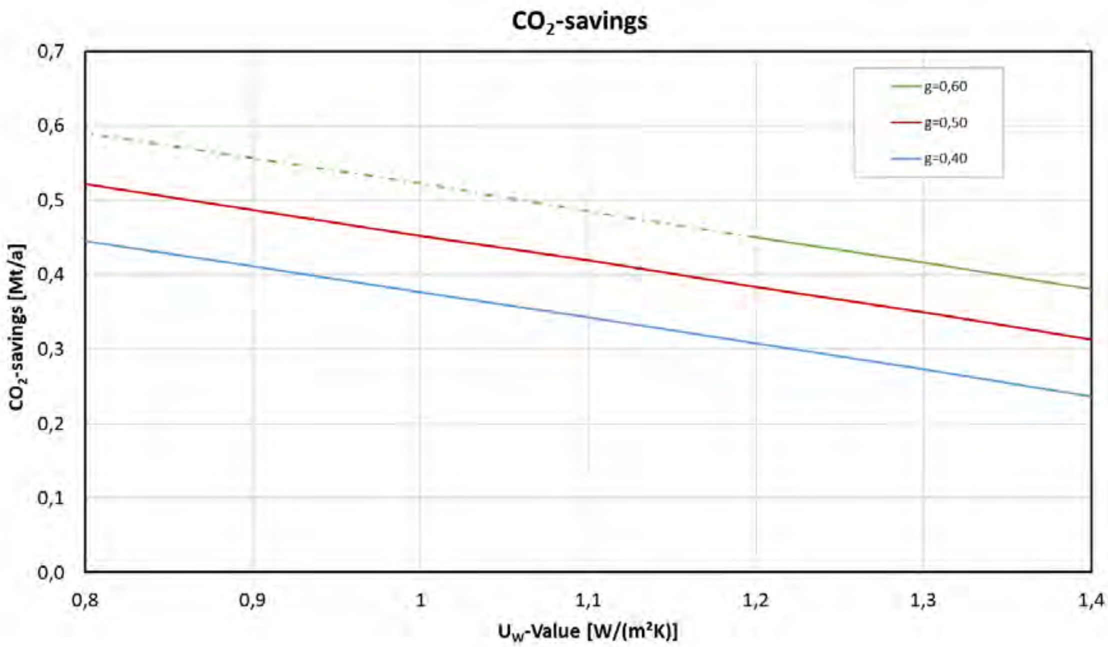


Figure D-96: CO_2-emission savings Latvia

D 17 Lithuania

D 17.1 Results building level (net energy)

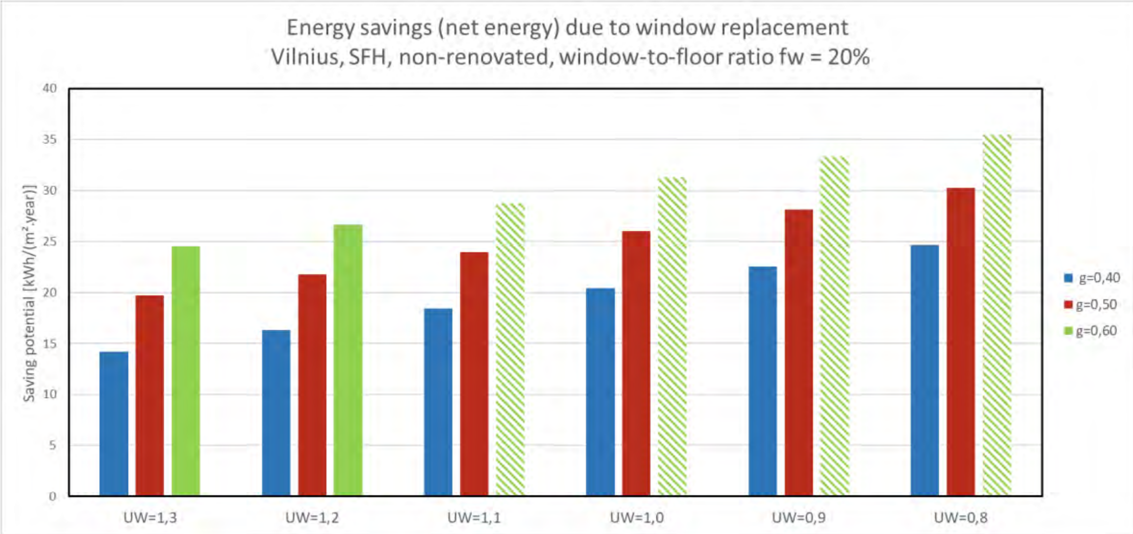


Figure D-97: Net energy savings for SFH, base case 1

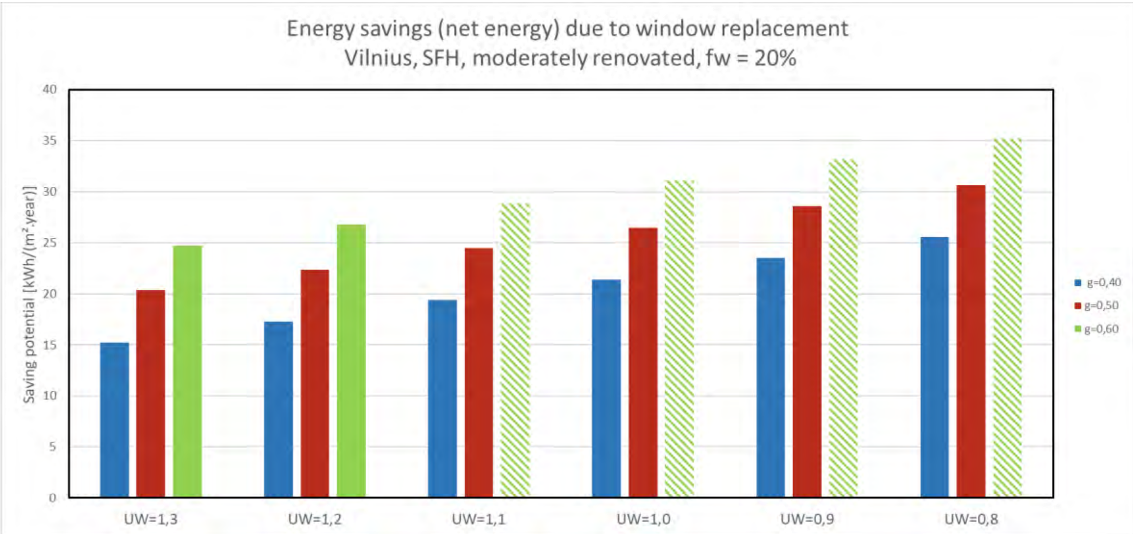


Figure D-98: Net energy savings for SFH, base case 2

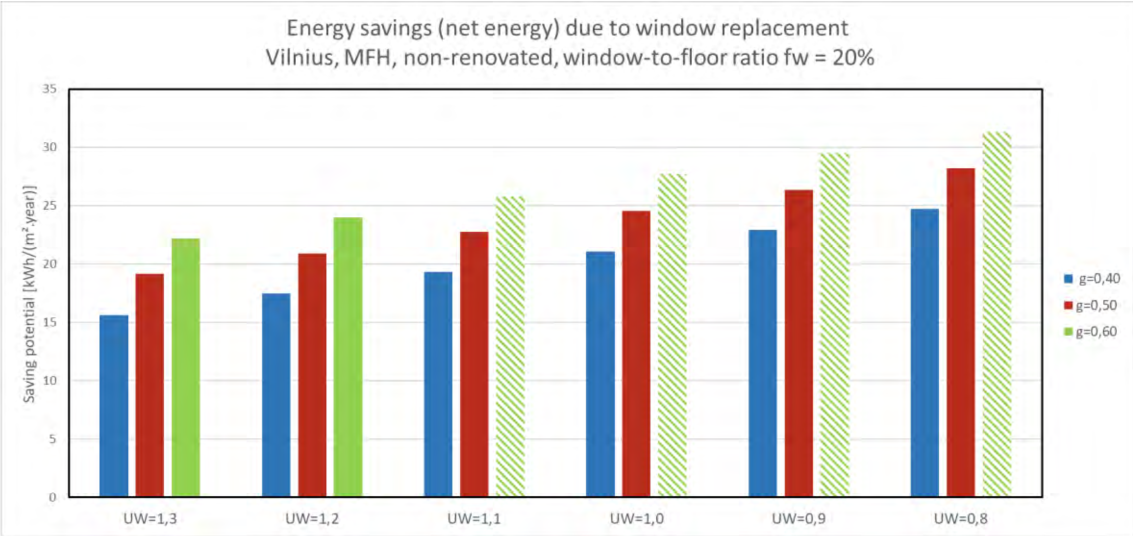


Figure D-99: Net energy savings for MFH, base case 1

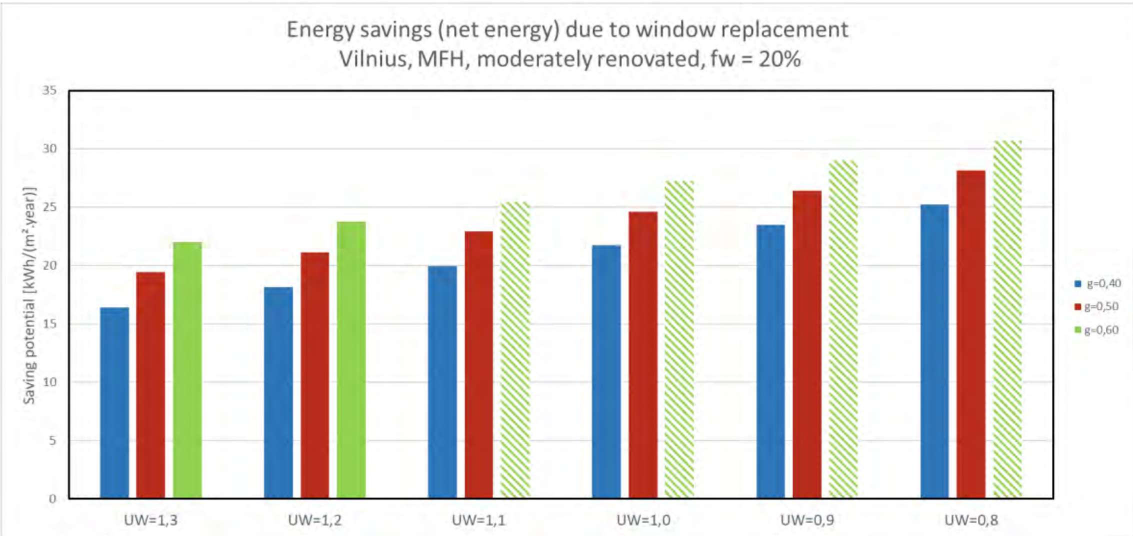


Figure D-100: Net energy savings for MFH, base case 2

D 17.2 Results national level (final energy and CO_2-savings)

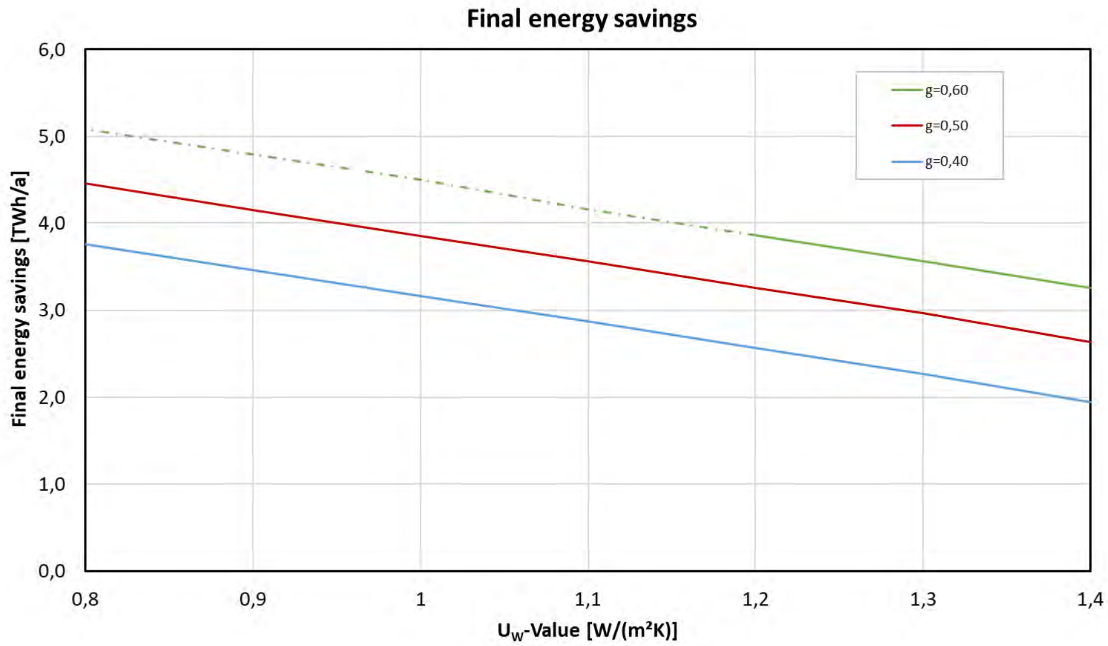


Figure D-101: Final energy savings Lithuania

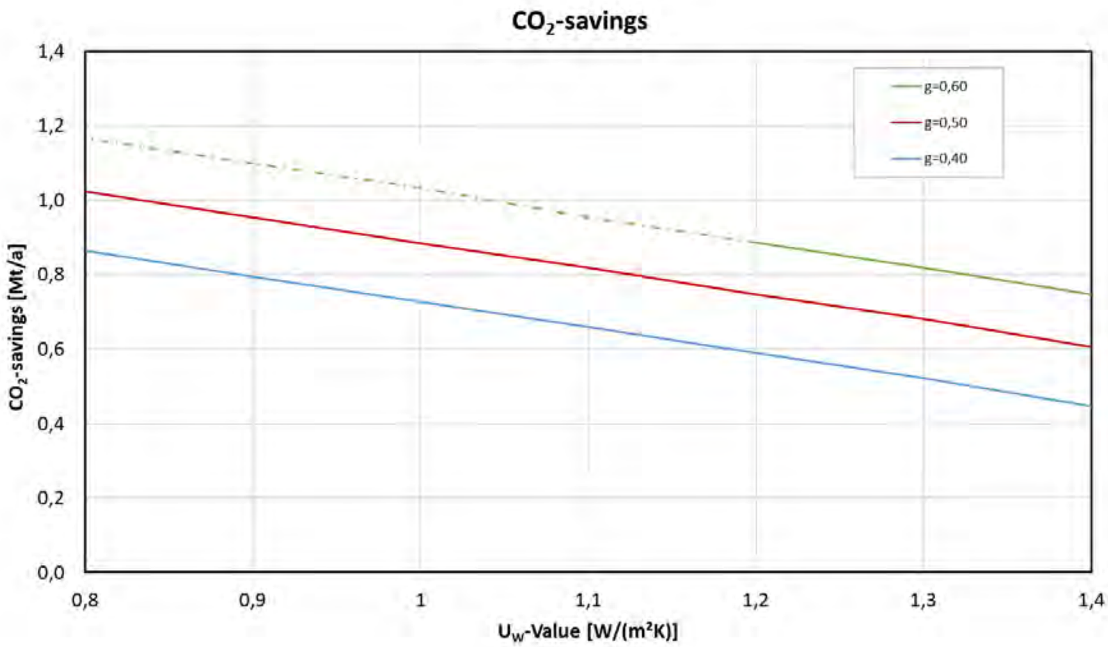


Figure D-102: CO_2-emission savings Lithuania

D 18 Luxembourg

D 18.1 Results building level (net energy)

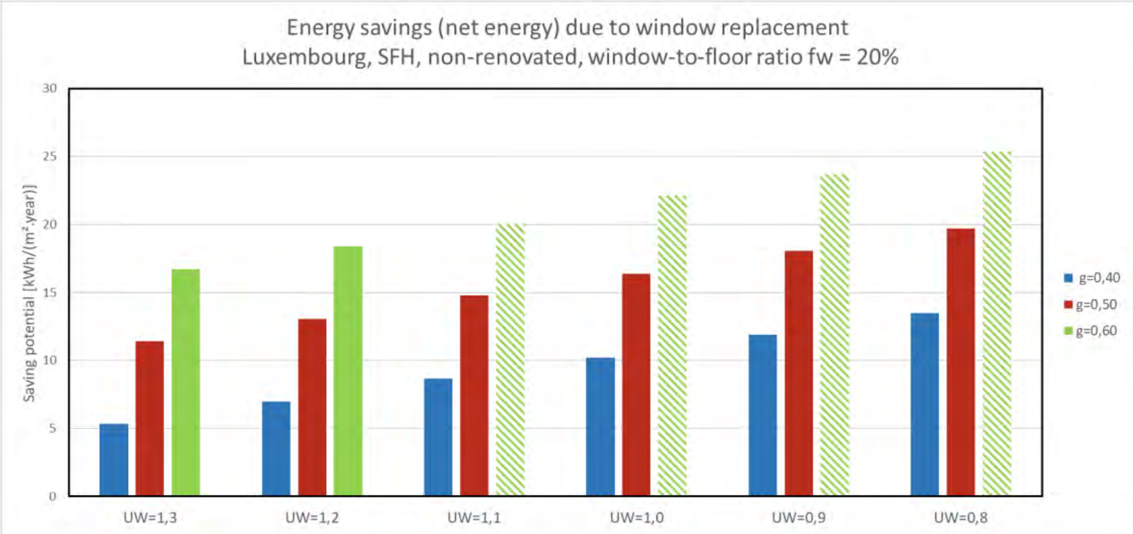


Figure D-103: Net energy savings for SFH, base case 1

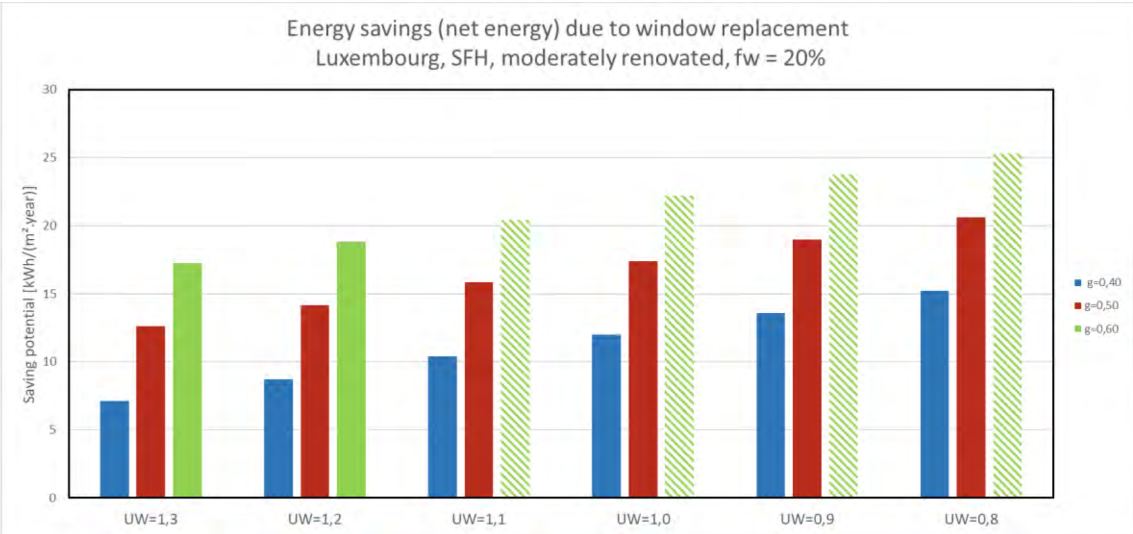


Figure D-104: Net energy savings for SFH, base case 2

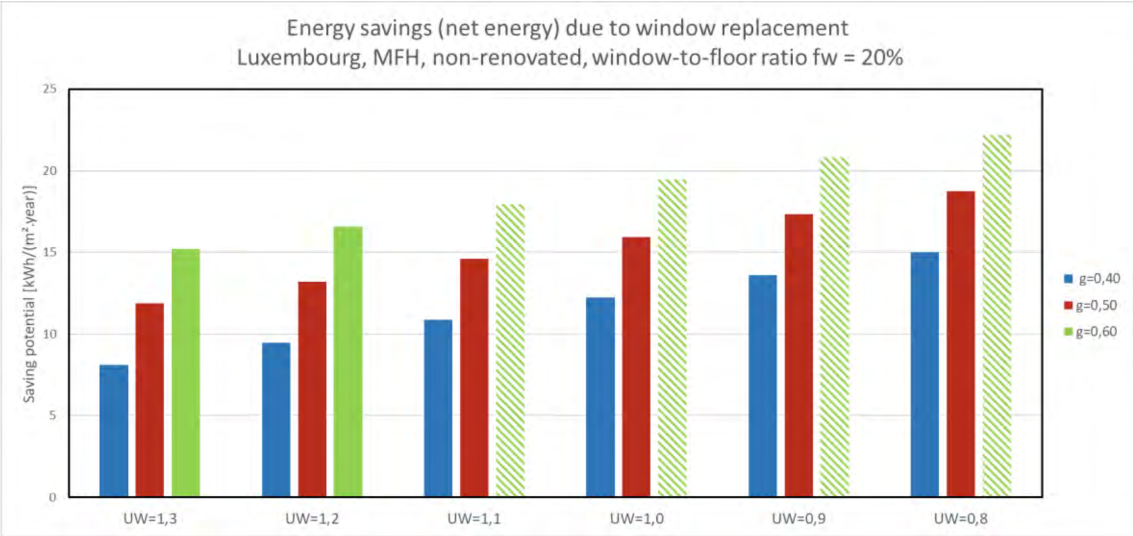


Figure D-105: Net energy savings for MFH, base case 1

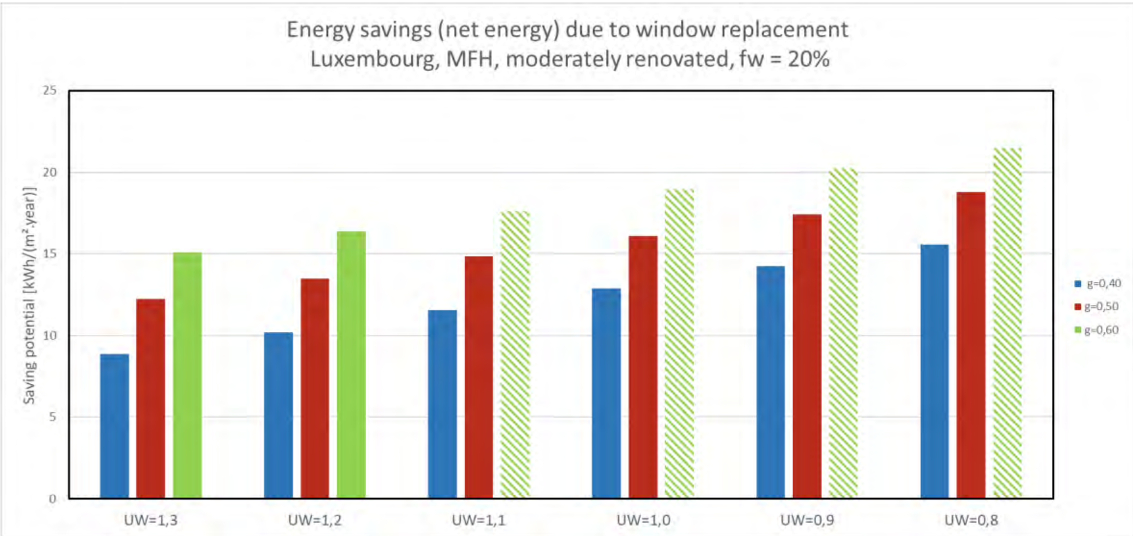


Figure D-106: Net energy savings for MFH, base case 2

D 18.2 Results national level (final energy and CO_2-savings)

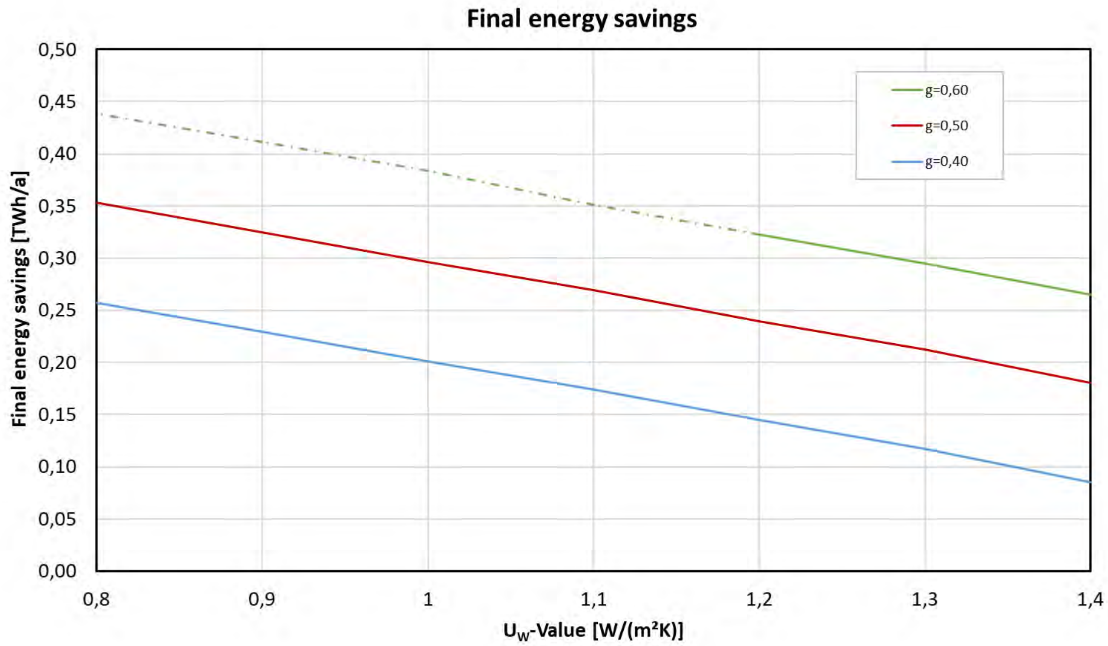


Figure D-107: Final energy savings Luxembourg

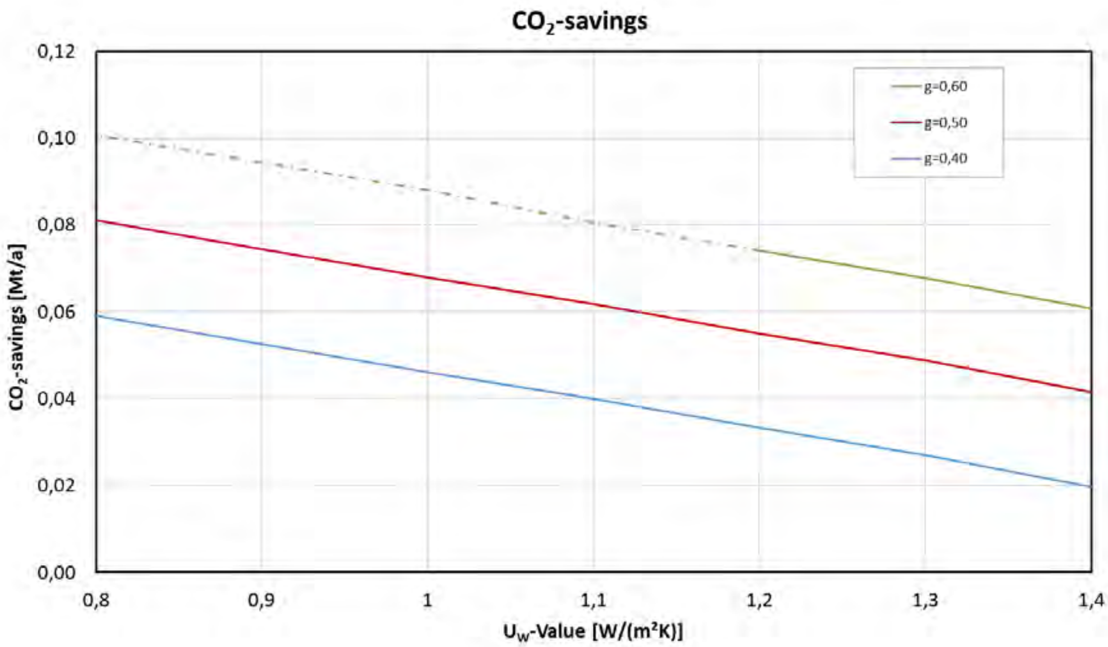


Figure D-108: CO_2-emission savings Luxembourg

D 19 Malta

D 19.1 Results building level (net energy)

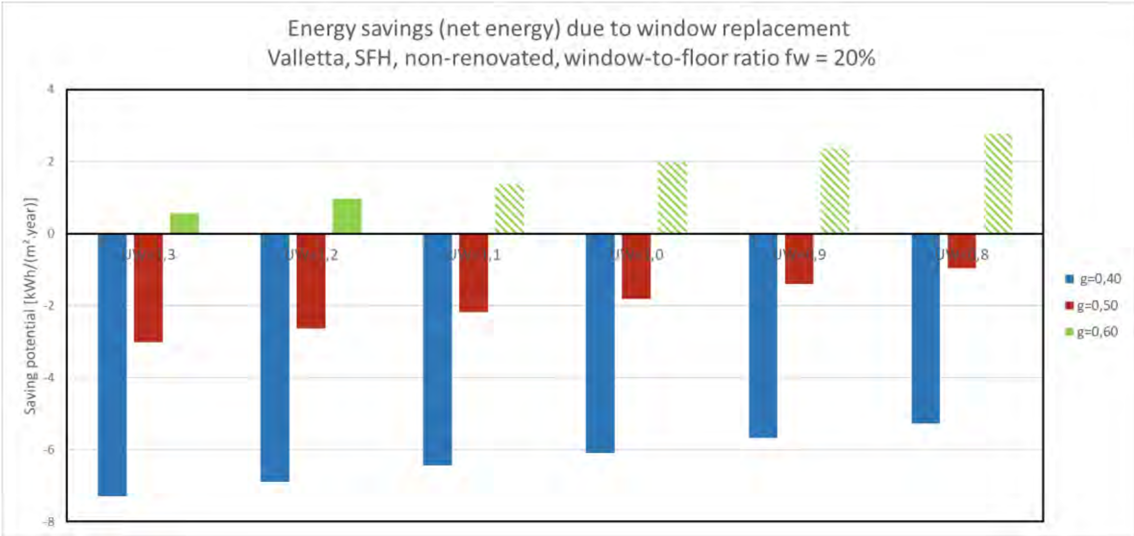


Figure D-109: Net energy savings for SFH, base case 1

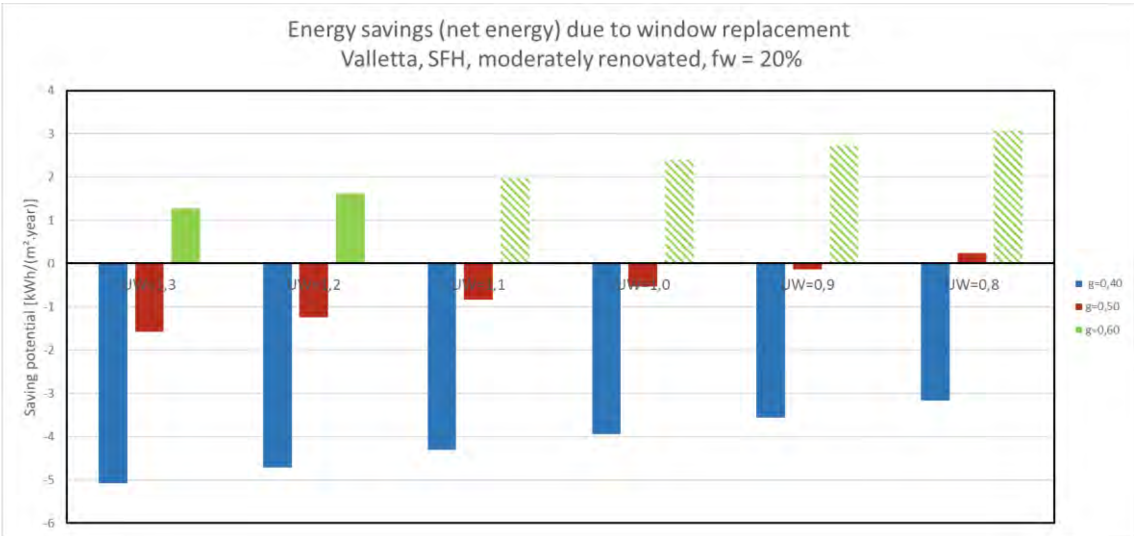


Figure D-110: Net energy savings for SFH, base case 2

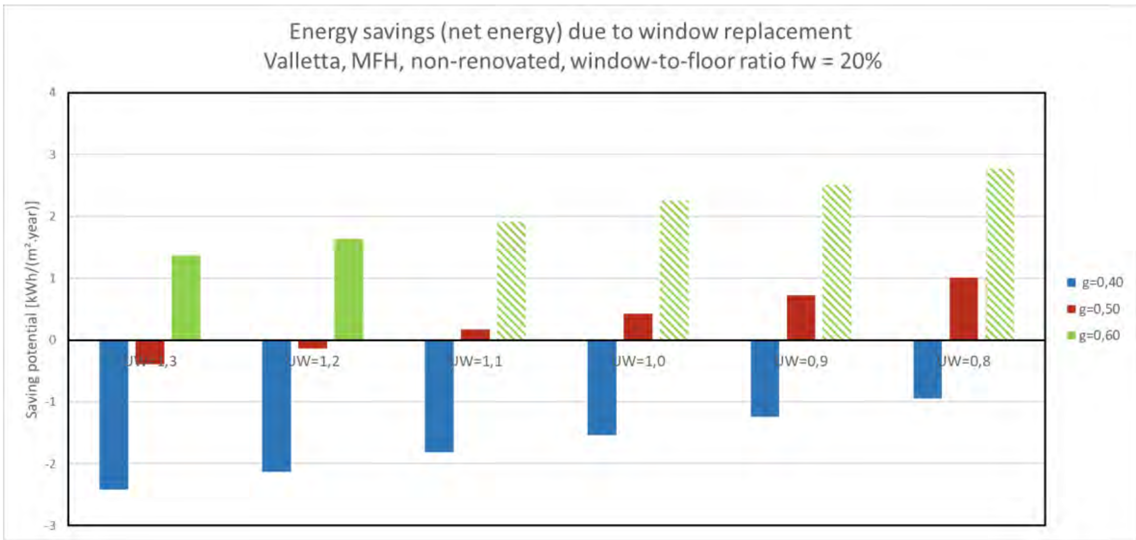


Figure D-111: Net energy savings for MFH, base case 1

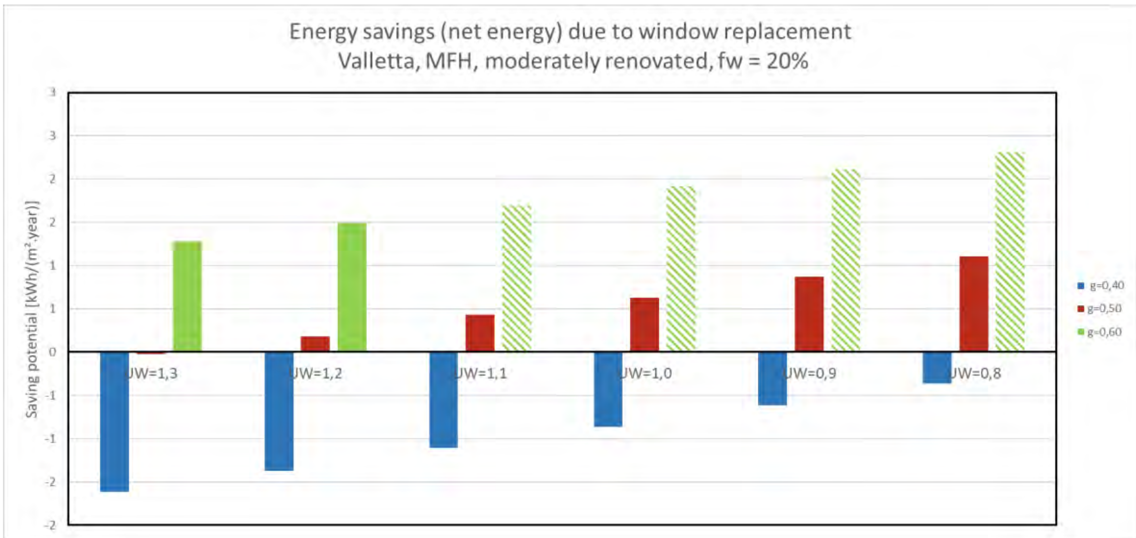


Figure D-112: Net energy savings for MFH, base case 2

D 19.2 Results national level (final energy and CO_2-savings)

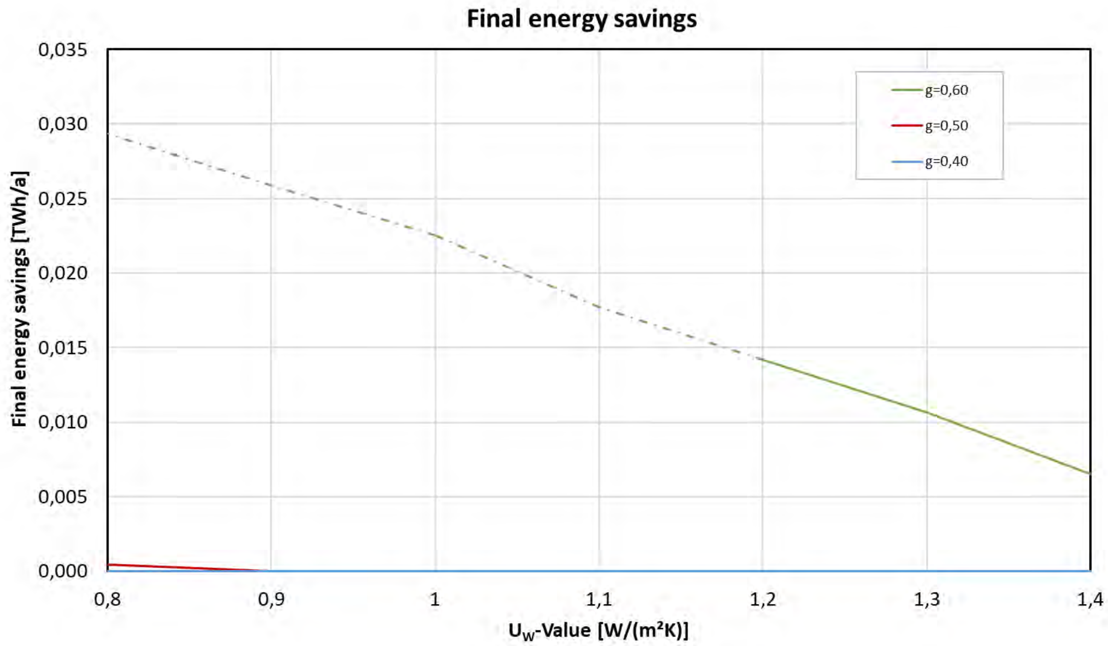


Figure D-113: Final energy savings Malta

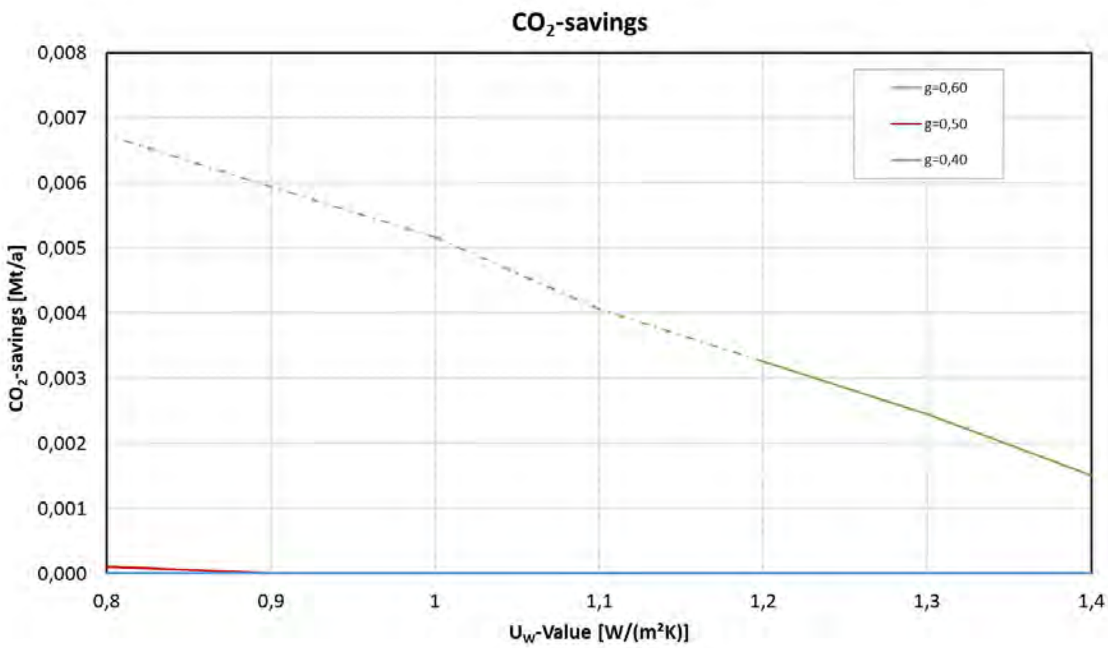


Figure D-114: CO_2-emission savings Malta

D 20 Netherlands

D 20.1 Results building level (net energy)

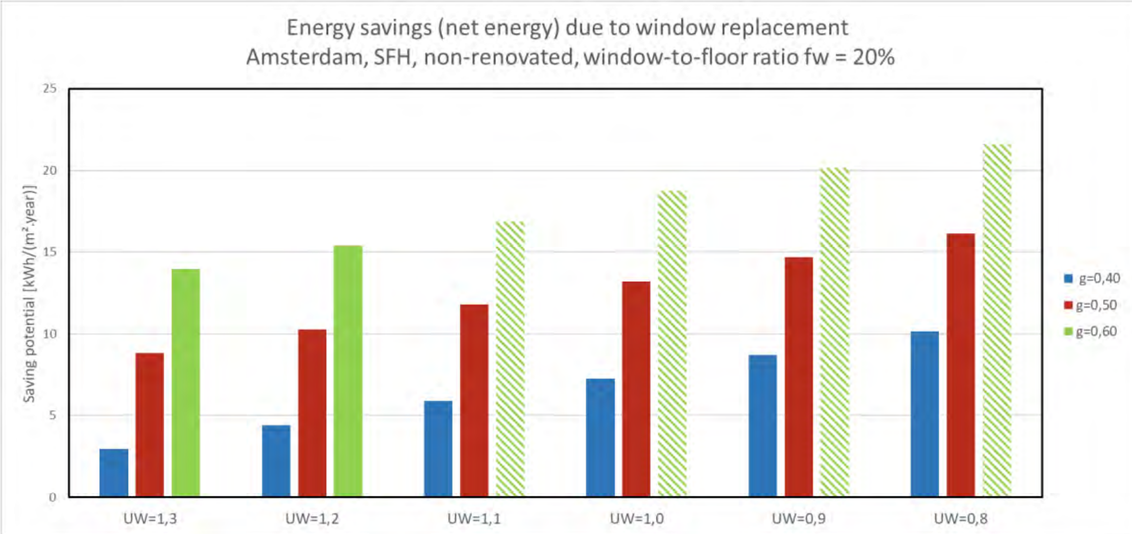


Figure D-115: Net energy savings for SFH, base case 1

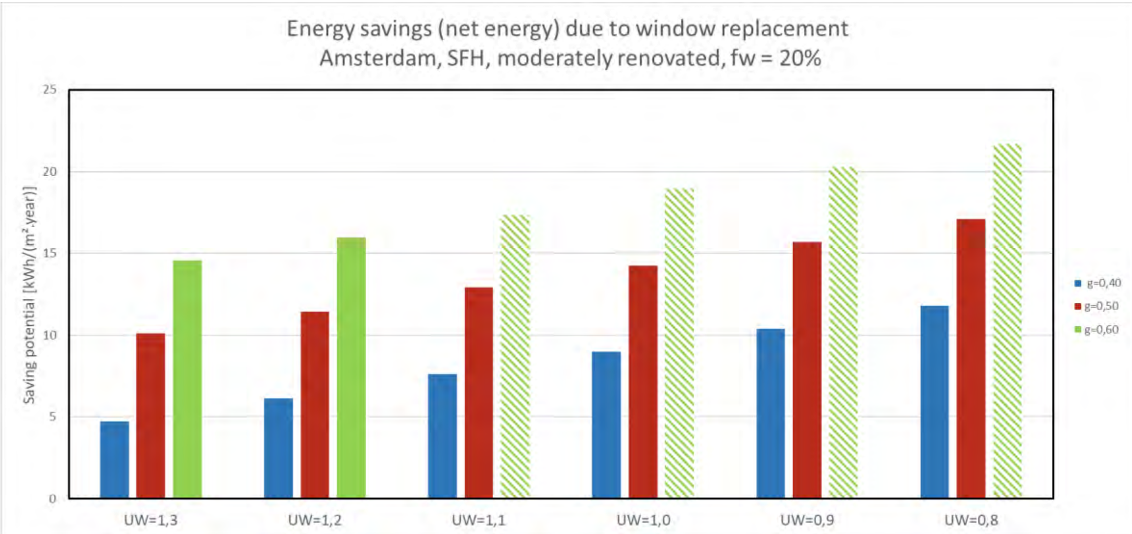


Figure D-116: Net energy savings for SFH, base case 2

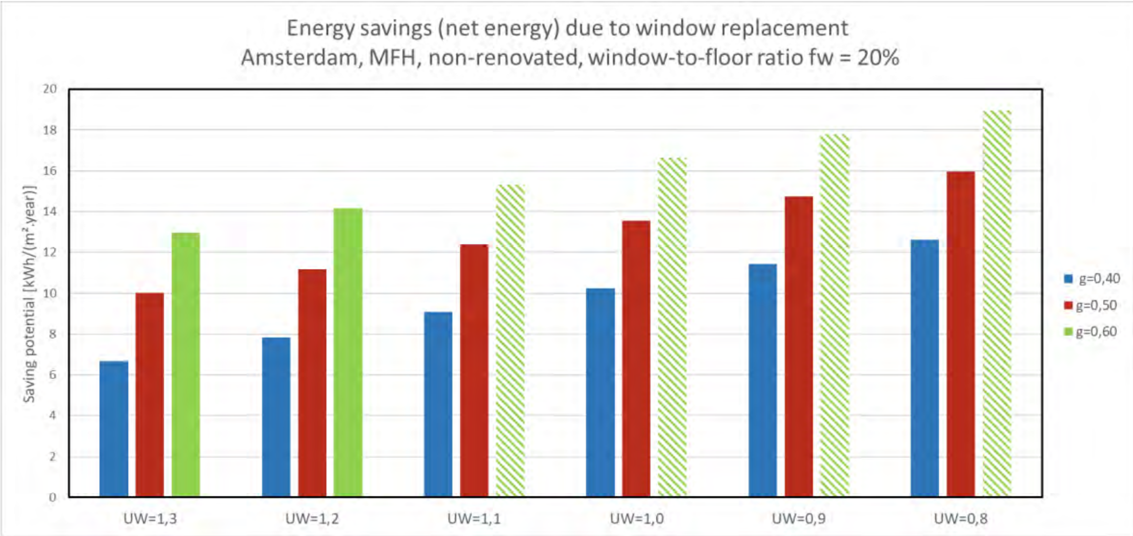


Figure D-117: Net energy savings for MFH, base case 1

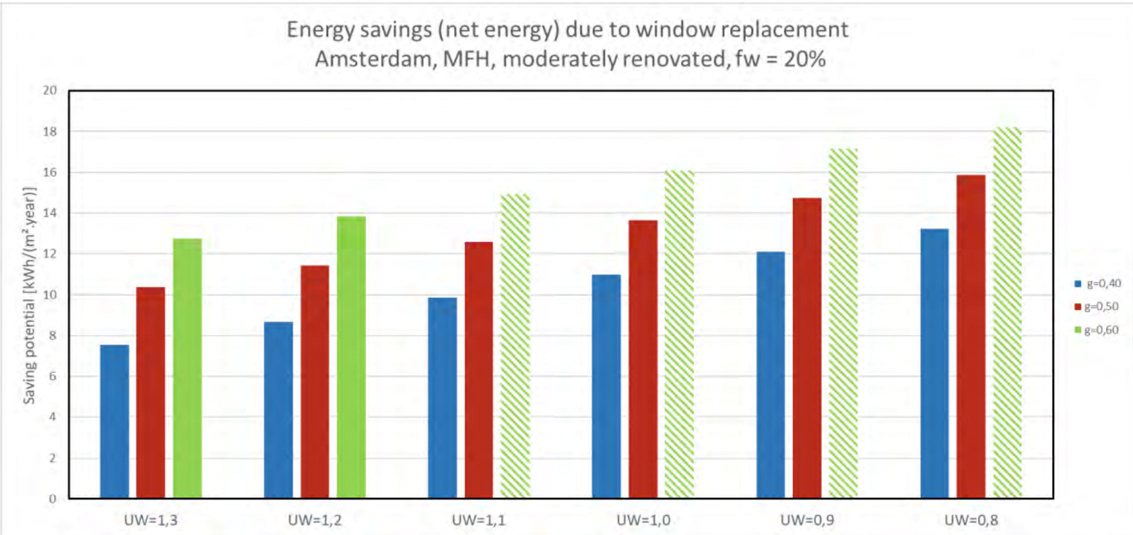


Figure D-118: Net energy savings for MFH, base case 2

D 20.2 Results national level (final energy and CO_2-savings)

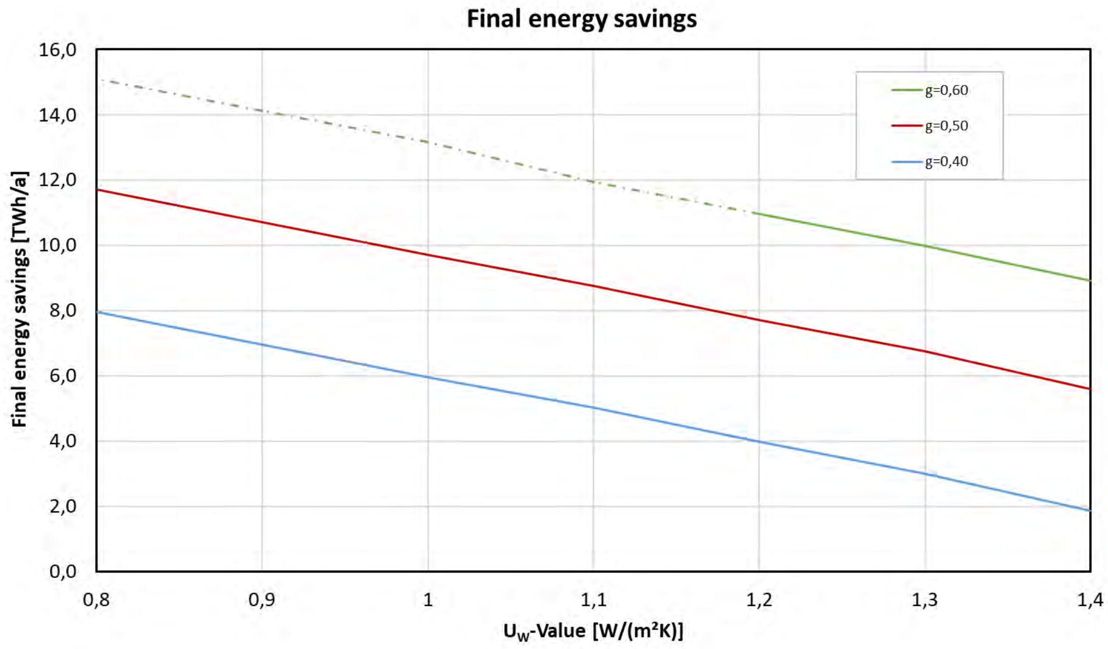


Figure D-119: Final energy savings Netherlands

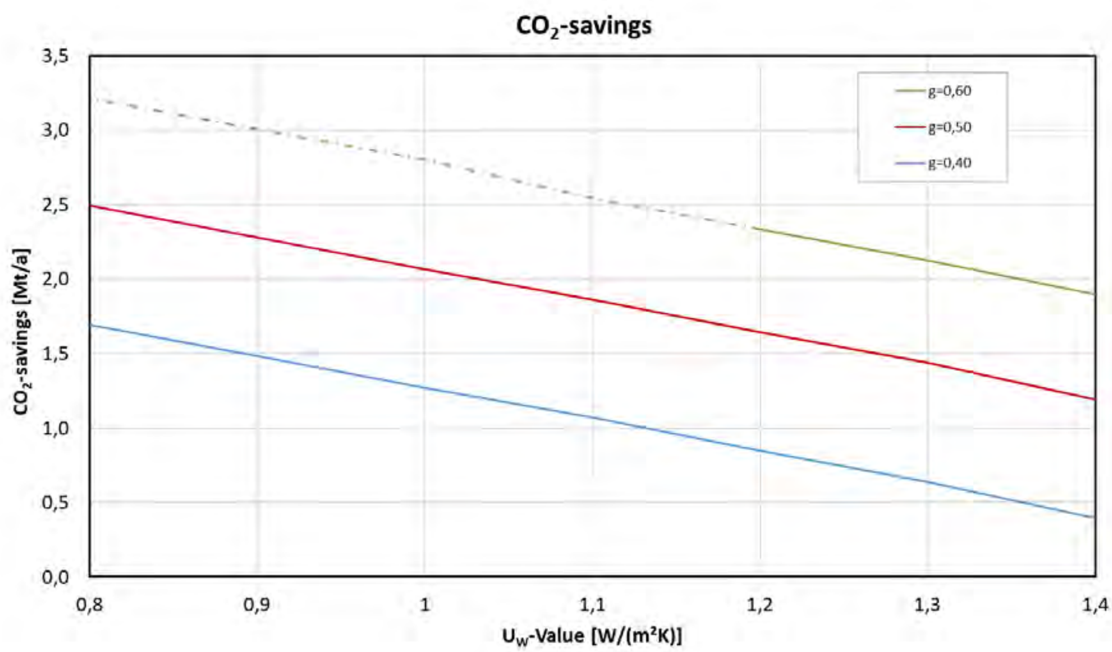


Figure D-120: CO_2-emission savings Netherlands

D 21 Poland

D 21.1 Results building level (net energy)

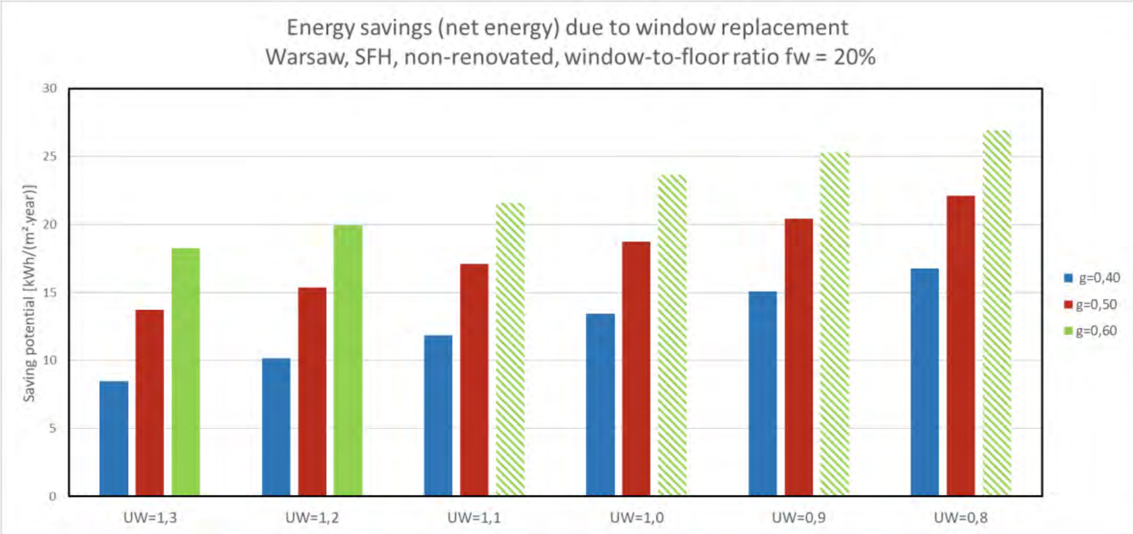


Figure D-121: Net energy savings for SFH, base case 1

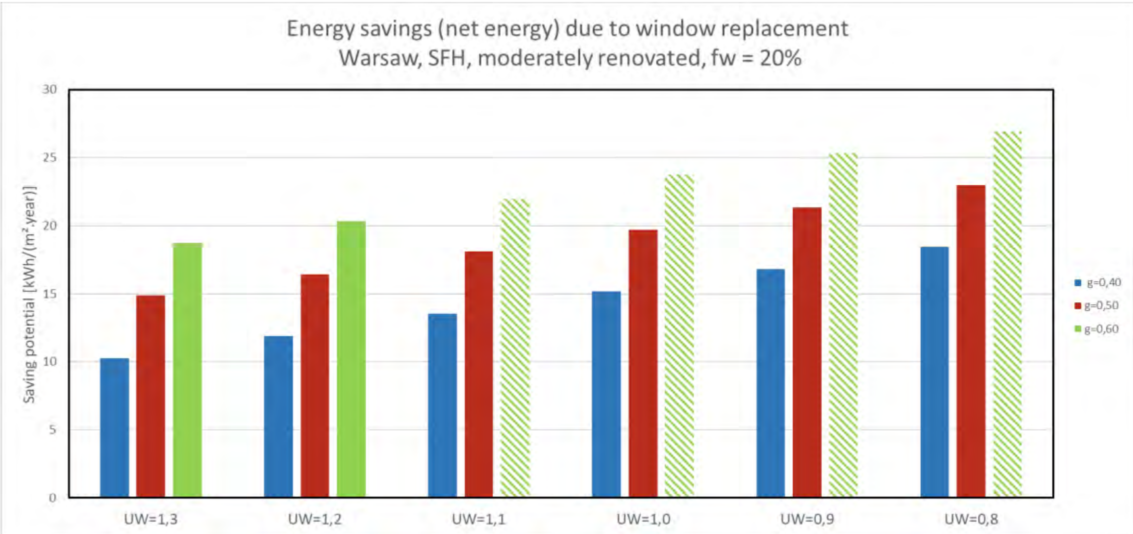


Figure D-122: Net energy savings for SFH, base case 2

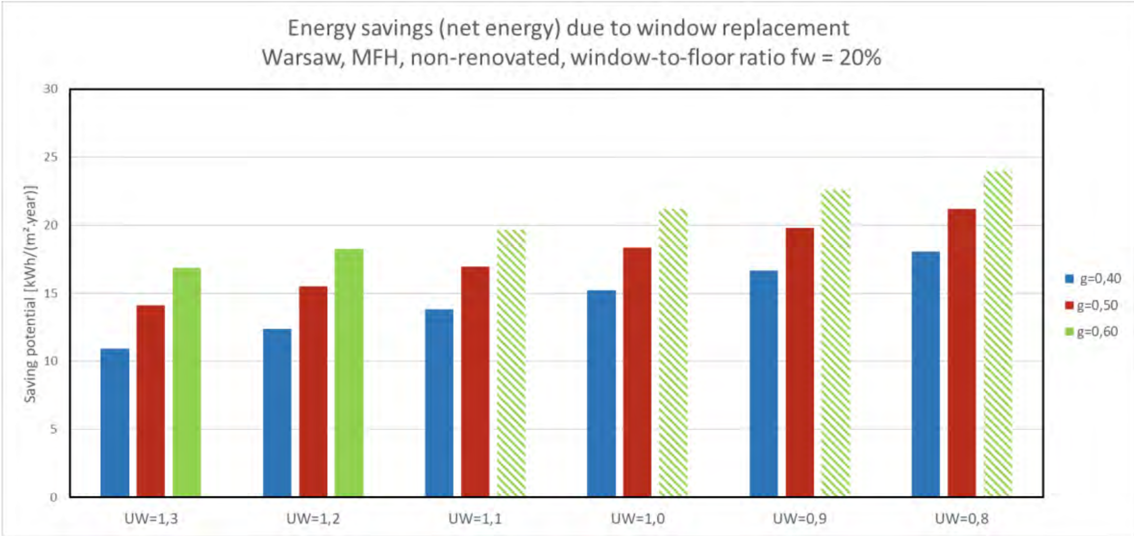


Figure D-123: Net energy savings for MFH, base case 1

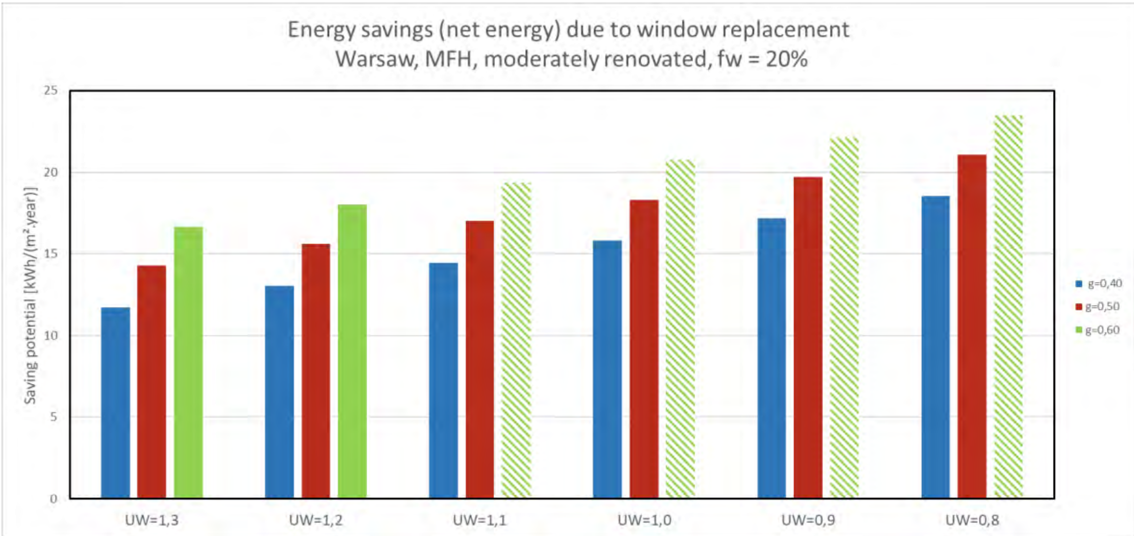


Figure D-124: Net energy savings for MFH, base case 2

D 21.2 Results national level (final energy and CO_2-savings)

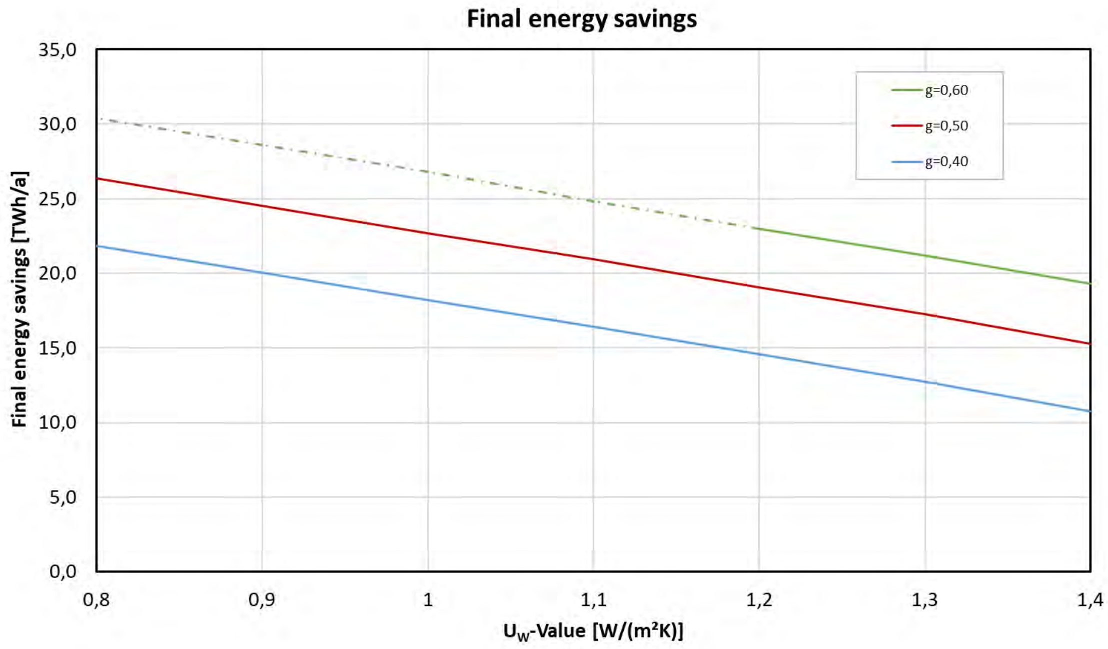


Figure D-125: Final energy savings Poland

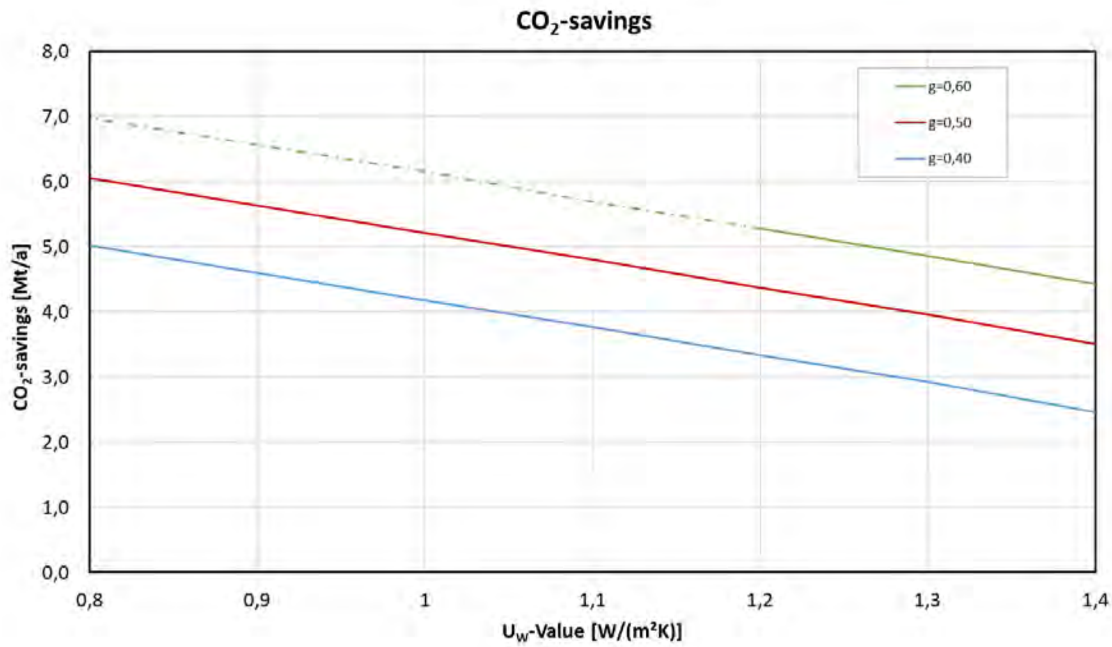


Figure D-126: CO_2-emission savings Poland

D 22 Portugal

D 22.1 Results building level (net energy)

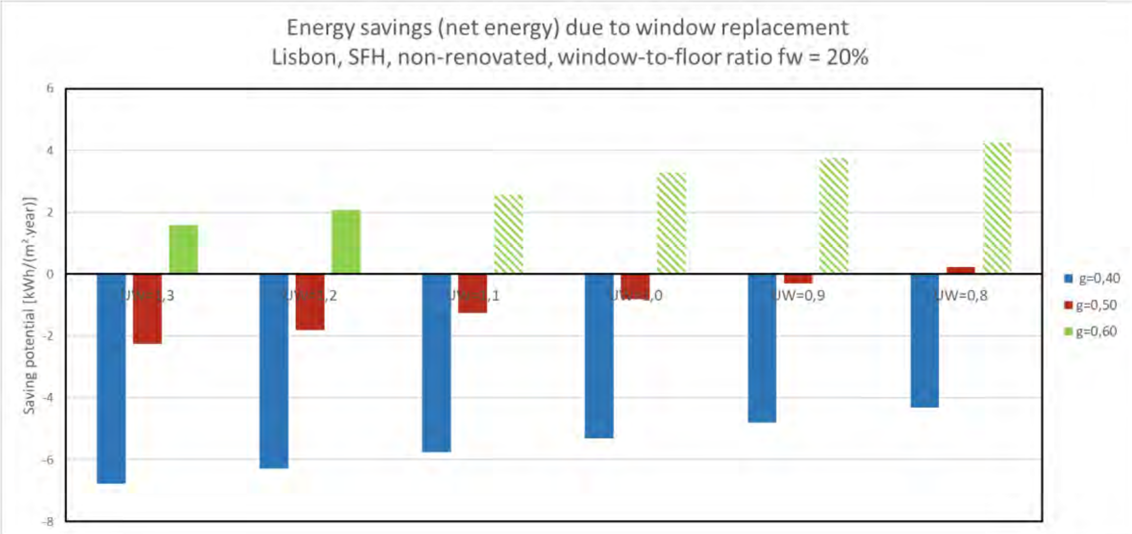


Figure D-127: Net energy savings for SFH, base case 1

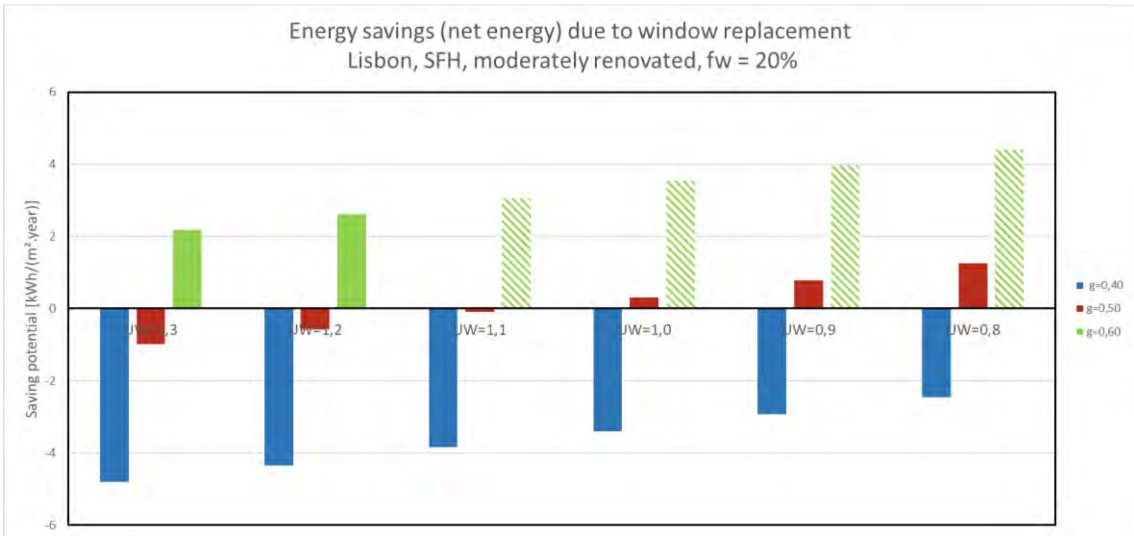


Figure D-128: Net energy savings for SFH, base case 2

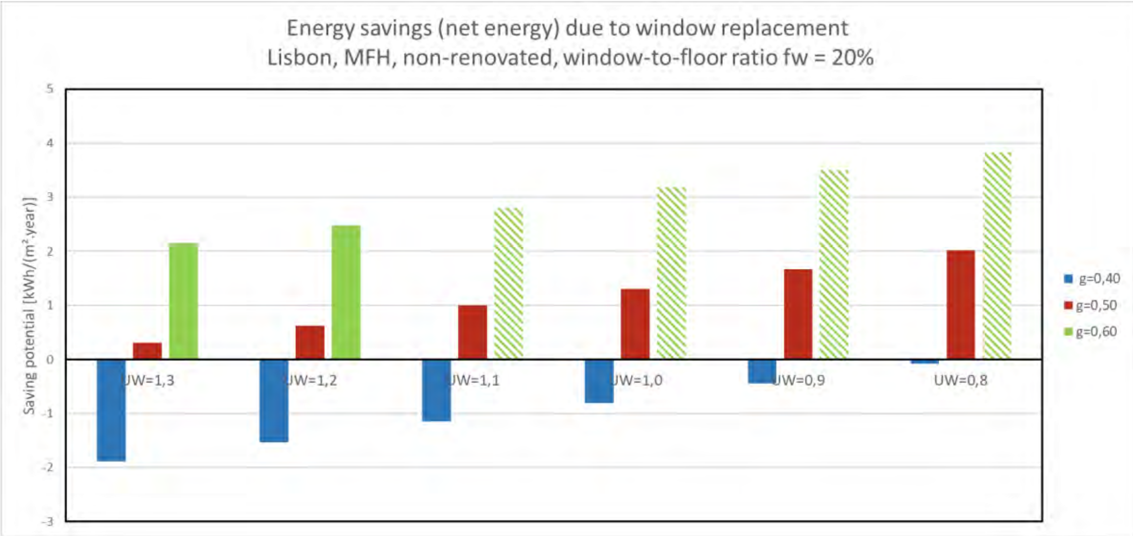


Figure D-129: Net energy savings for MFH, base case 1

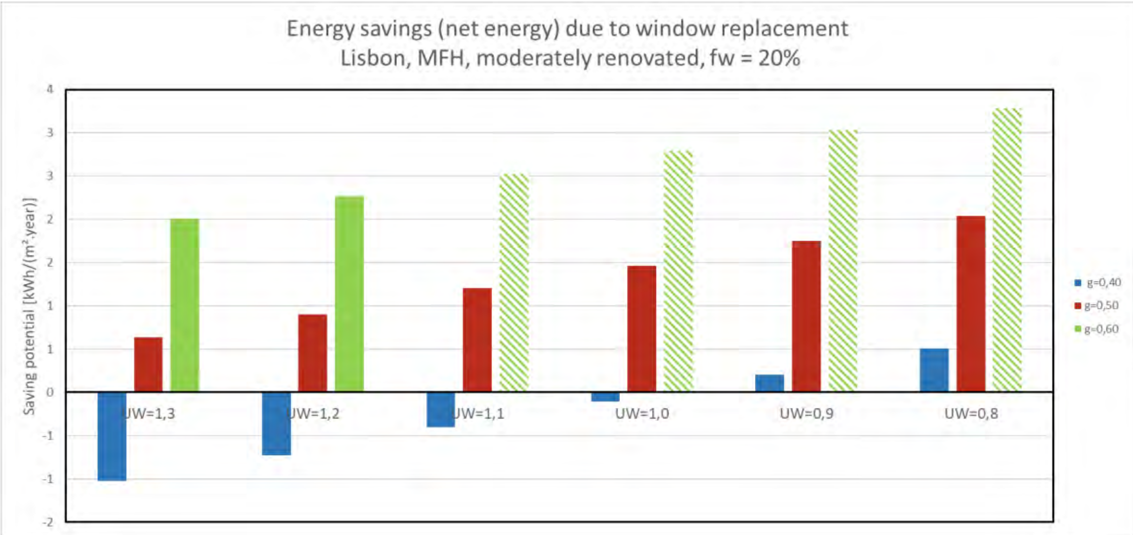


Figure D-130: Net energy savings for MFH, base case 2

D 22.2 Results national level (final energy and CO_2-savings)

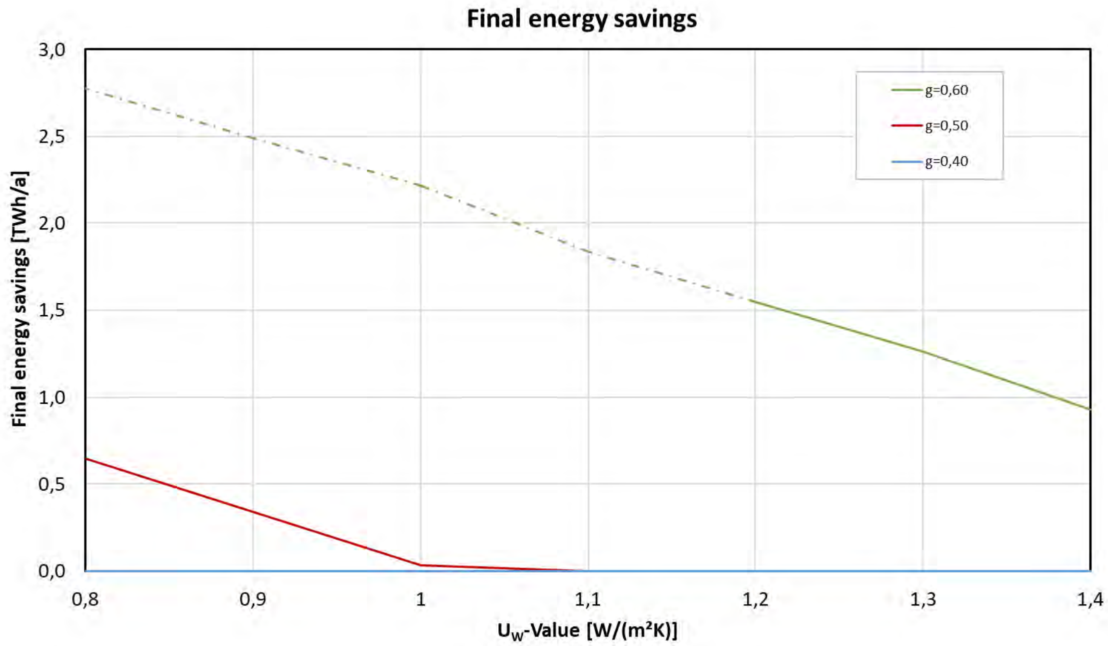


Figure D-131: Final energy savings Portugal

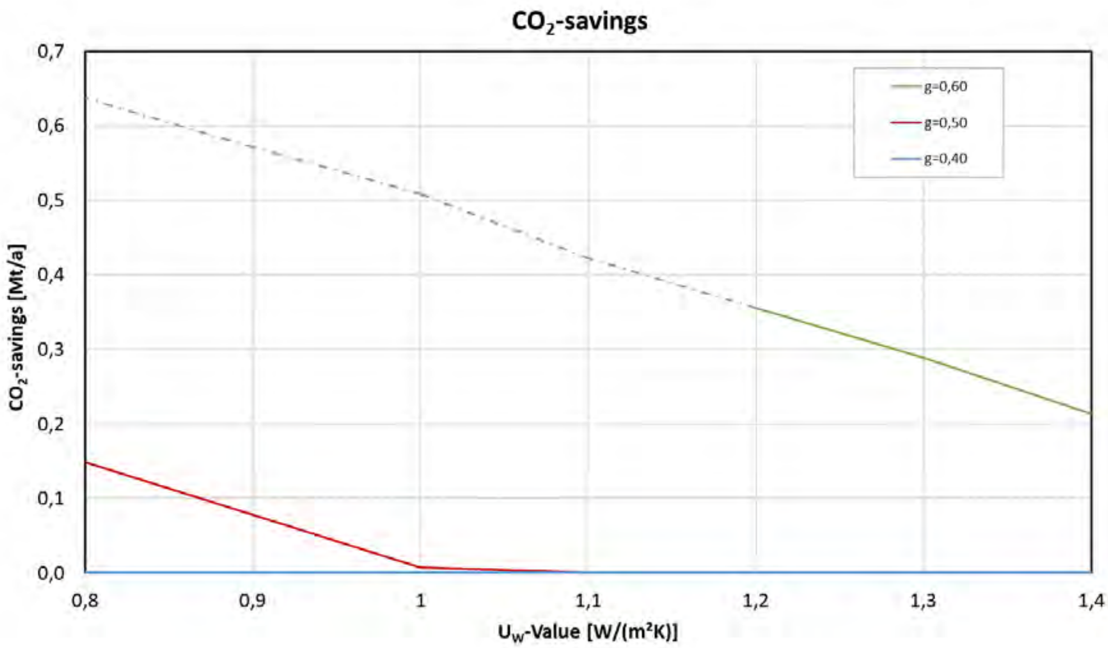


Figure D-132: CO_2-emission savings Portugal

D 23 Romania

D 23.1 Results building level (net energy)

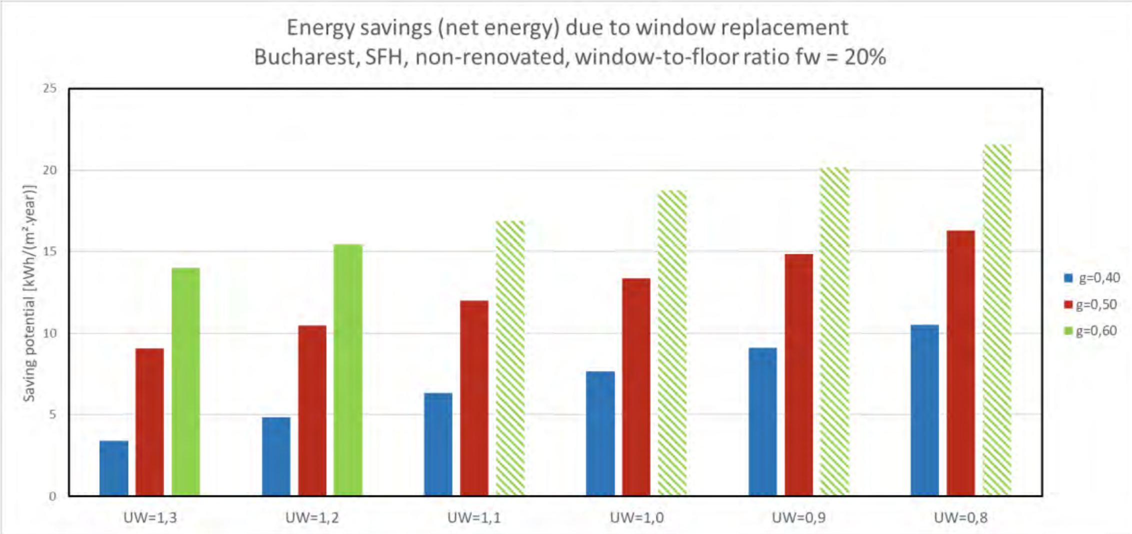


Figure D-133: Net energy savings for SFH, base case 1

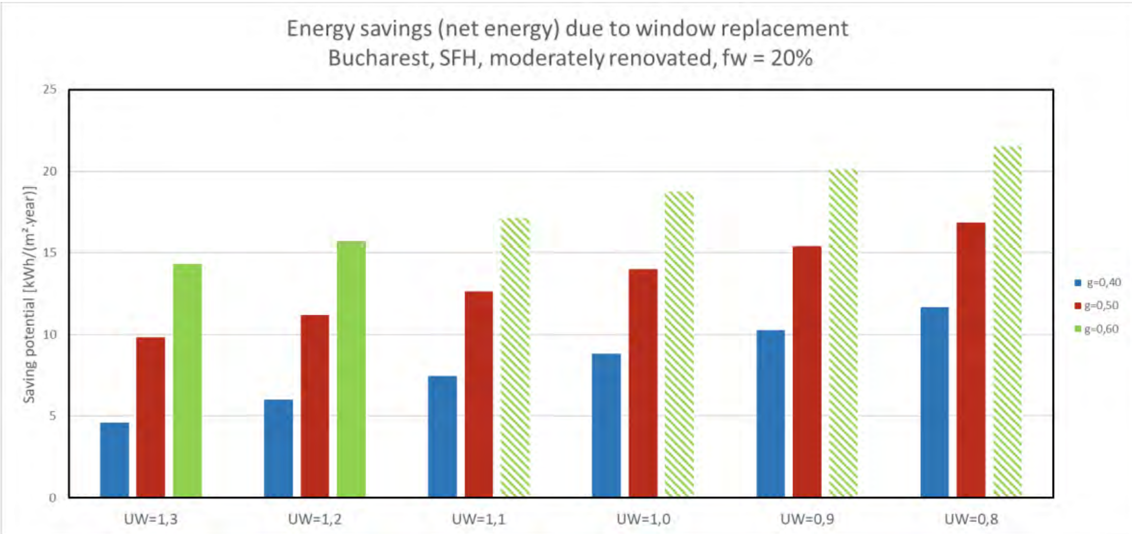


Figure D-134: Net energy savings for SFH, base case 2

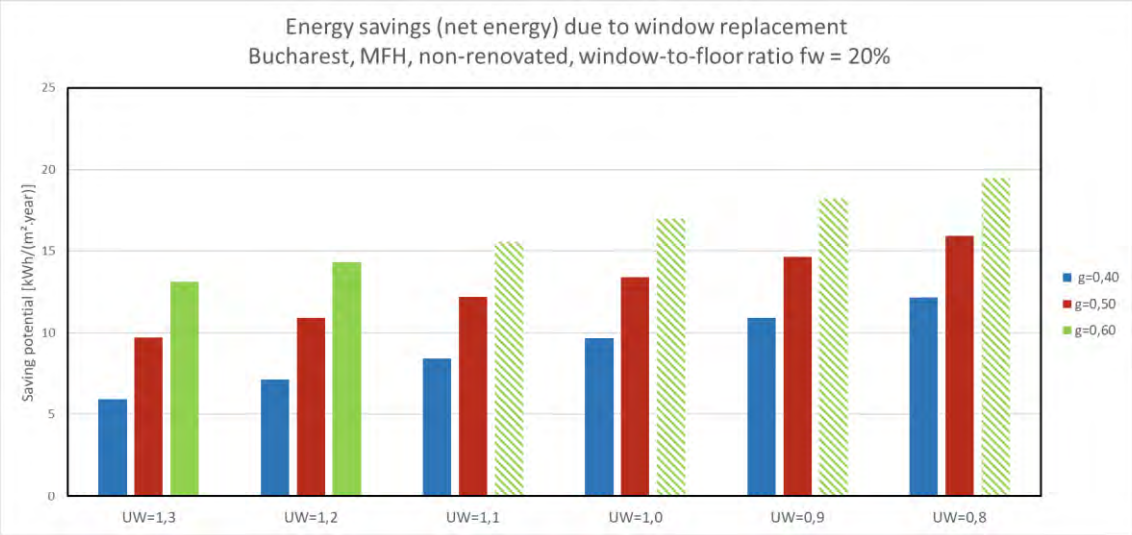


Figure D-135: Net energy savings for MFH, base case 1

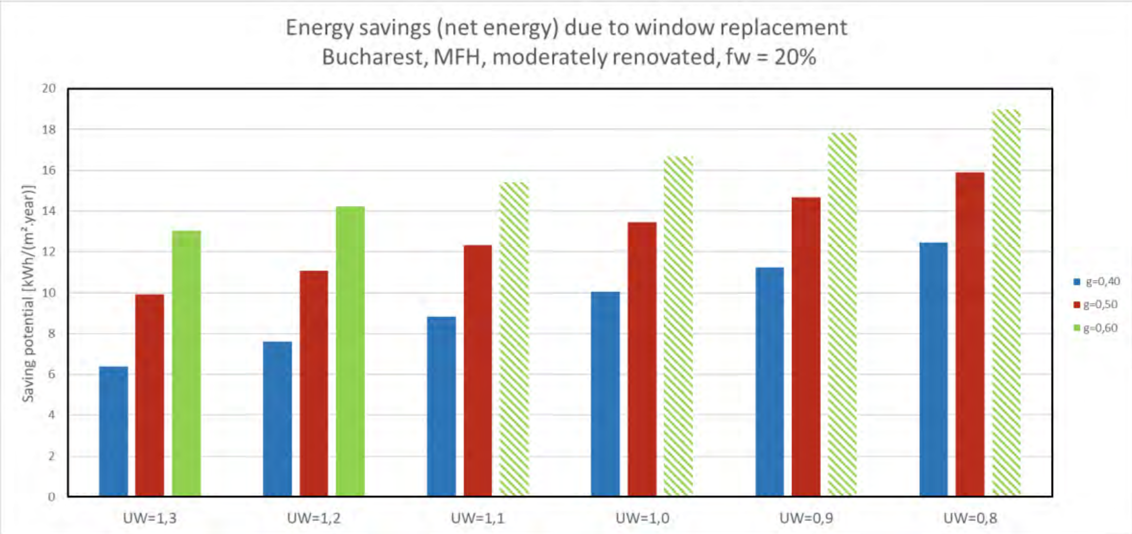


Figure D-136: Net energy savings for MFH, base case 2

D 23.2 Results national level (final energy and CO_2-savings)

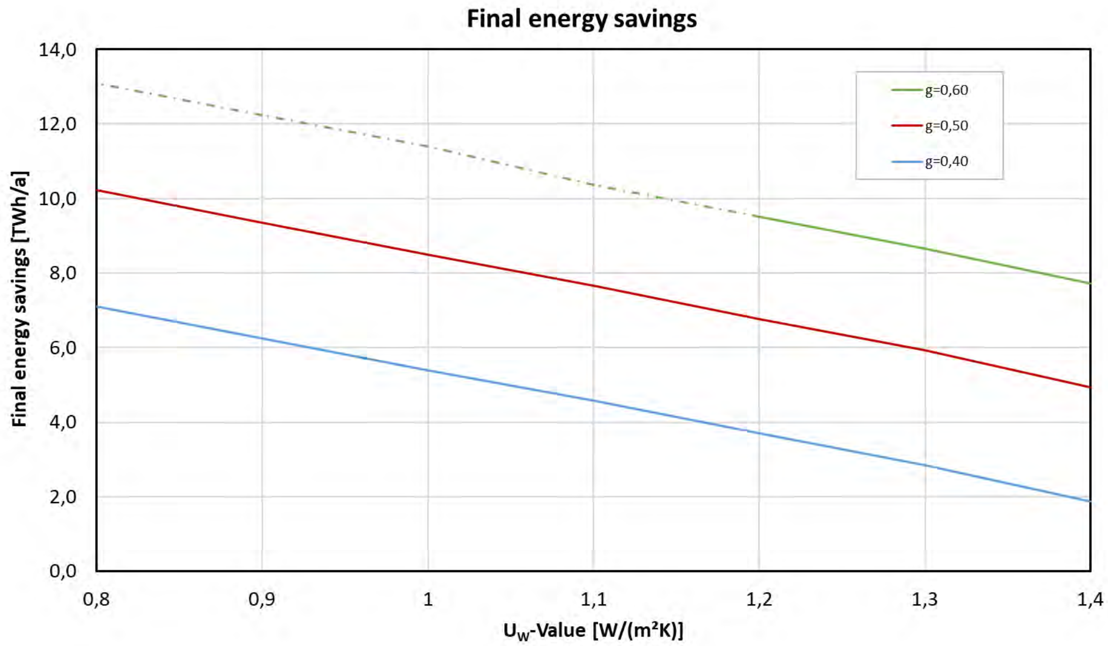


Figure D-137: Final energy savings Romania

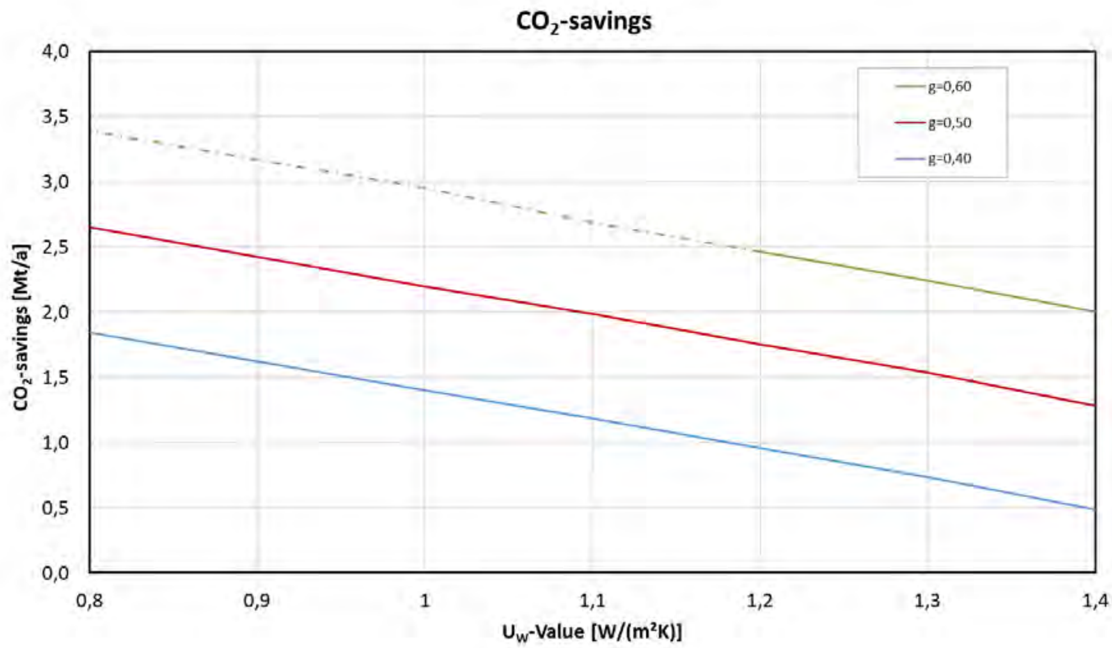


Figure D-138: CO_2-emission savings Romania

D 24 Slovakia

D 24.1 Results building level (net energy)

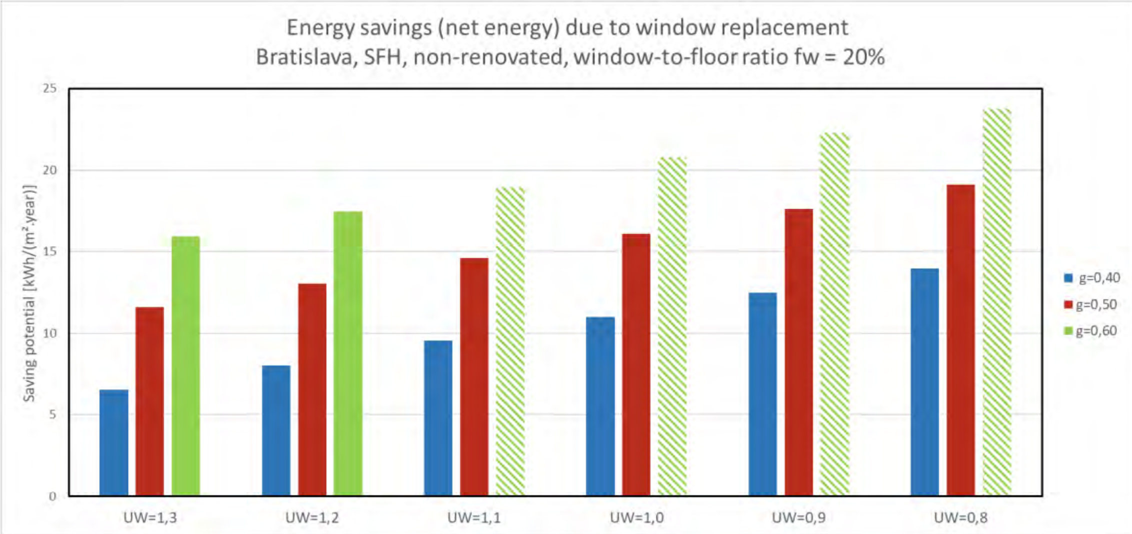


Figure D-139: Net energy savings for SFH, base case 1

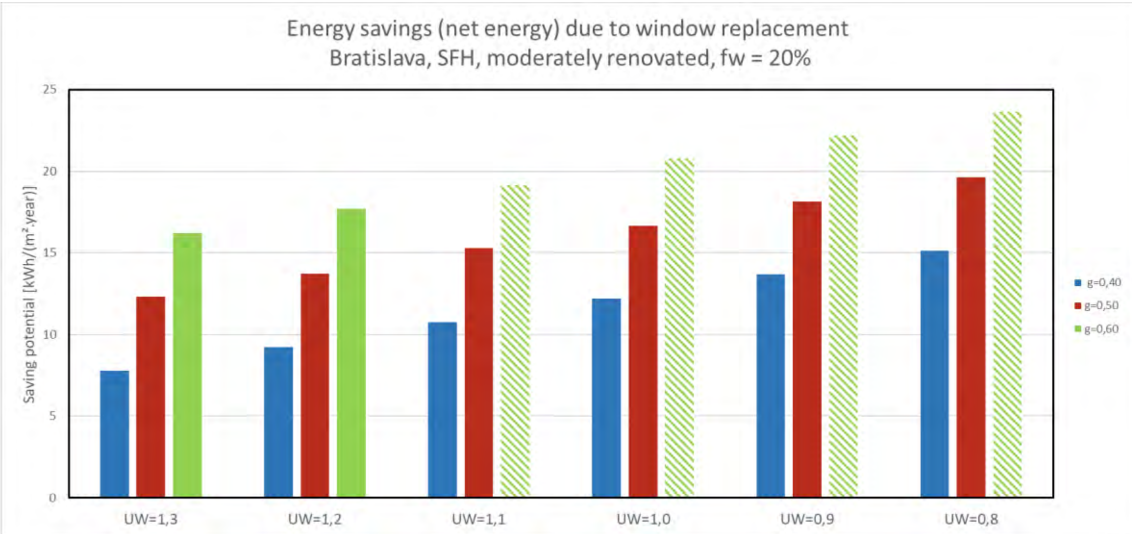


Figure D-140: Net energy savings for SFH, base case 2

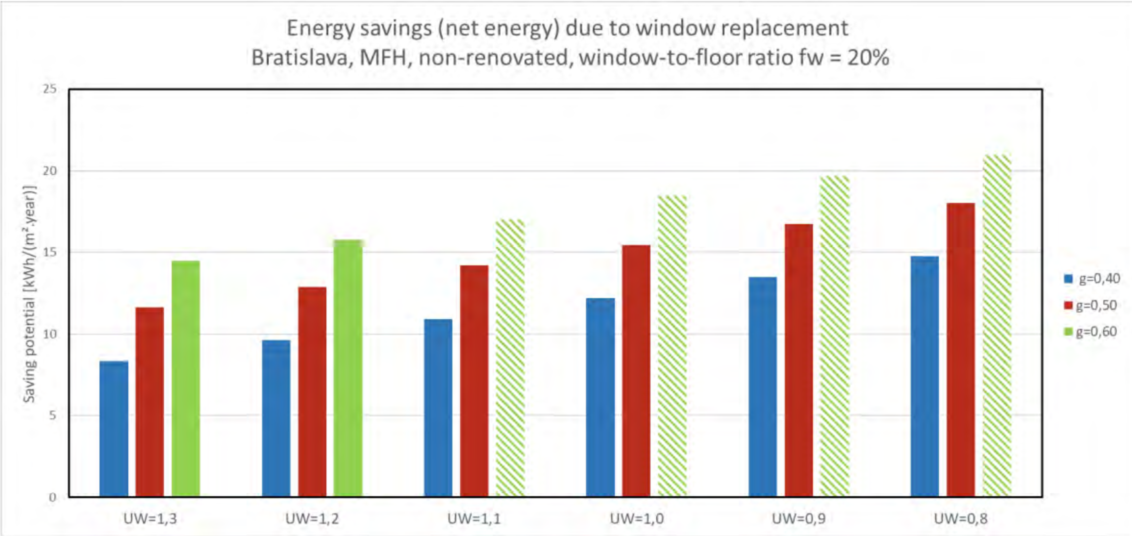


Figure D-141: Net energy savings for MFH, base case 1

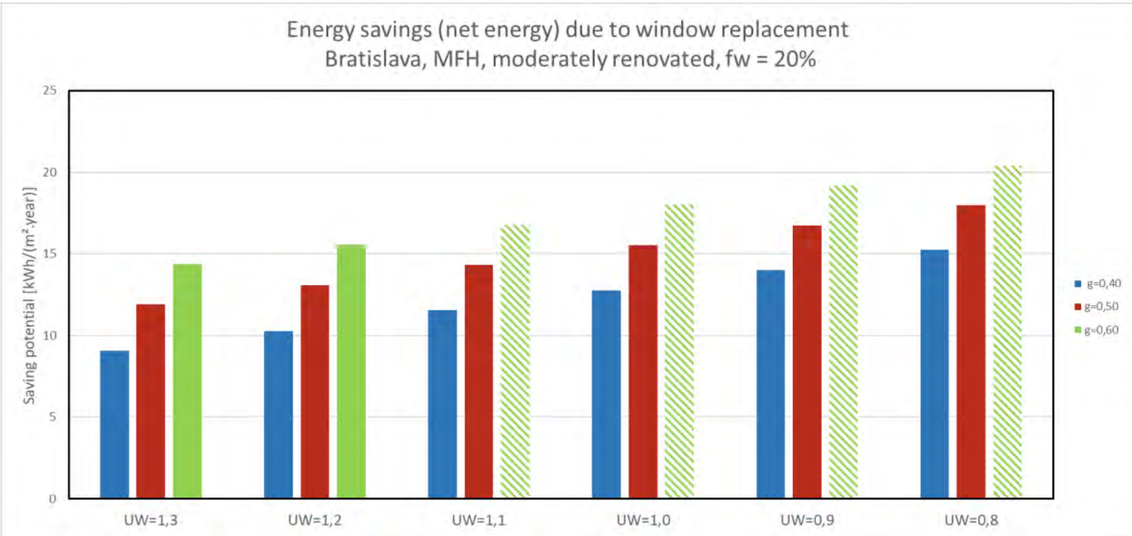


Figure D-142: Net energy savings for MFH, base case 2

D 24.2 Results national level (final energy and CO_2-savings)

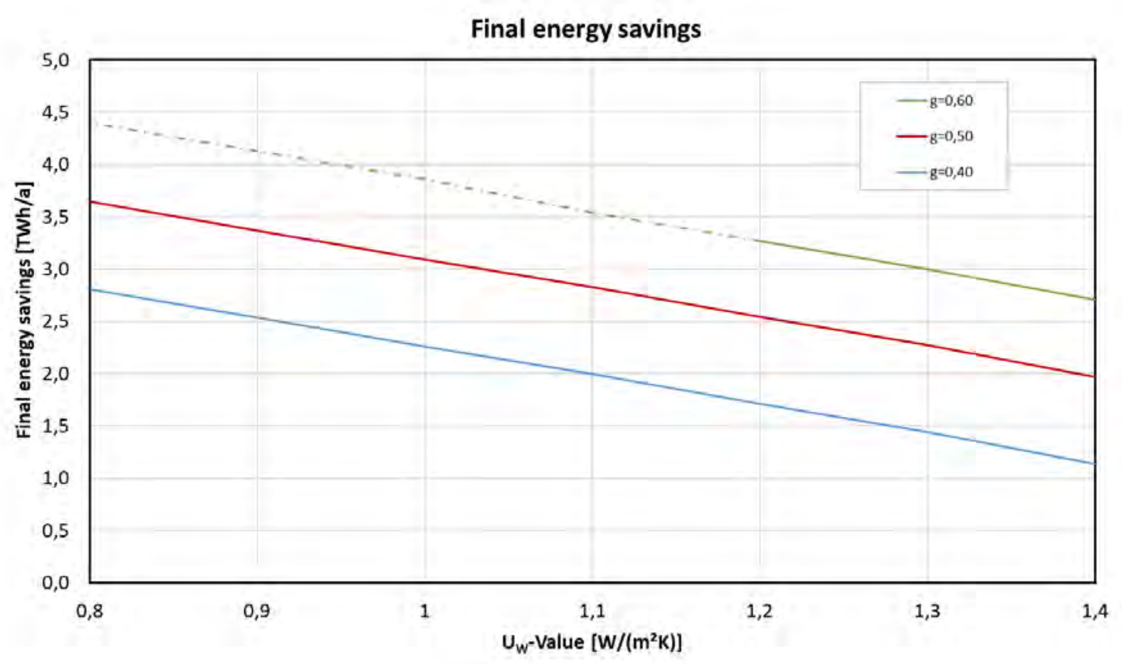


Figure D-143: Final energy savings Slovakia

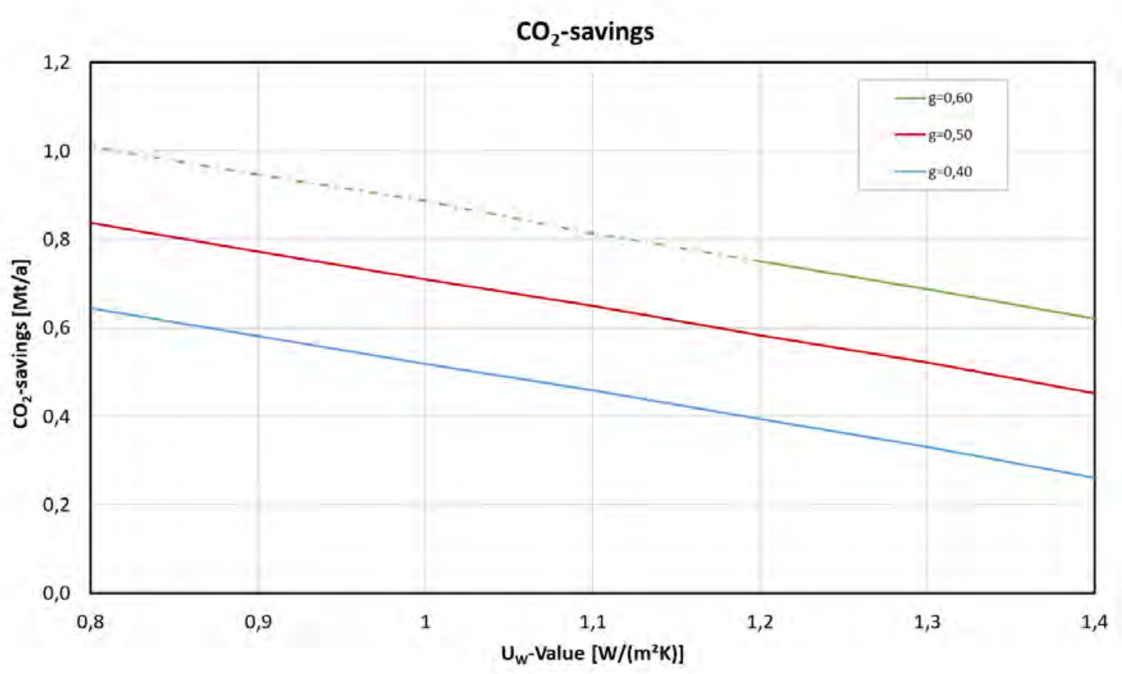


Figure D-144: CO_2-emission savings Slovakia

D 25 Slovenia

D 25.1 Results building level (net energy)

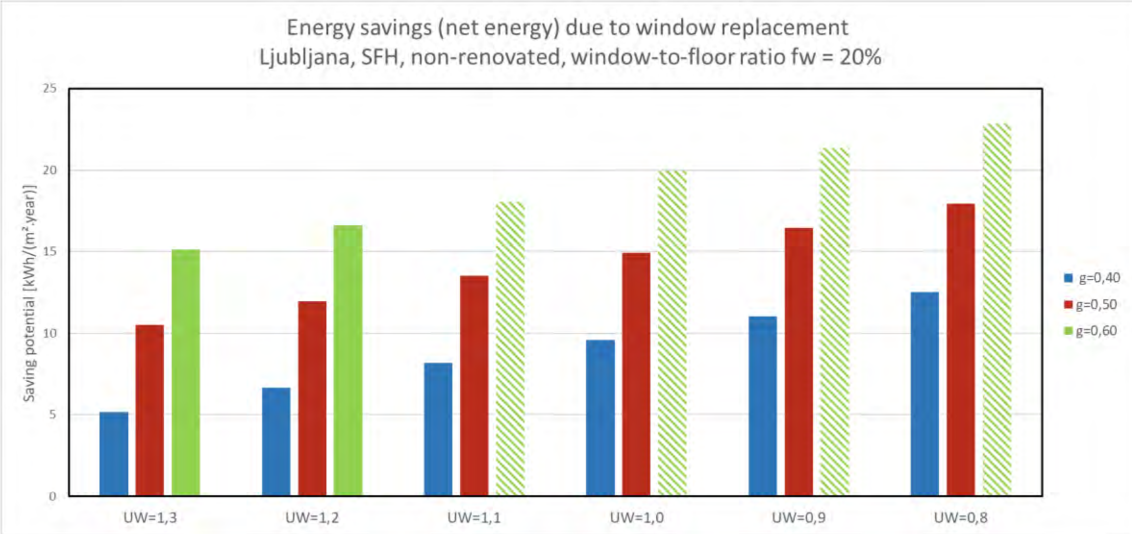


Figure D-145: Net energy savings for SFH, base case 1

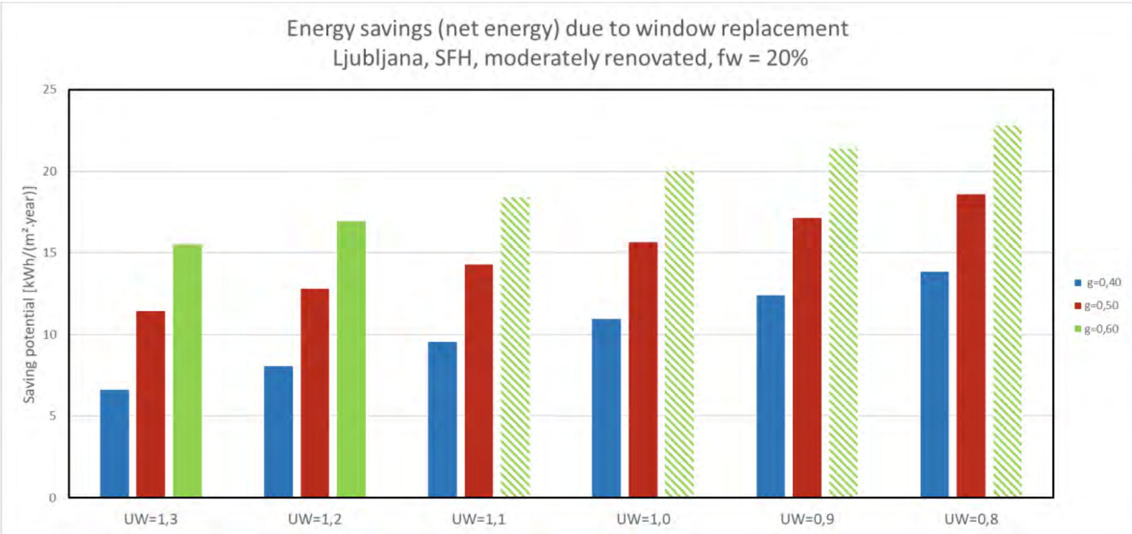


Figure D-146: Net energy savings for SFH, base case 2

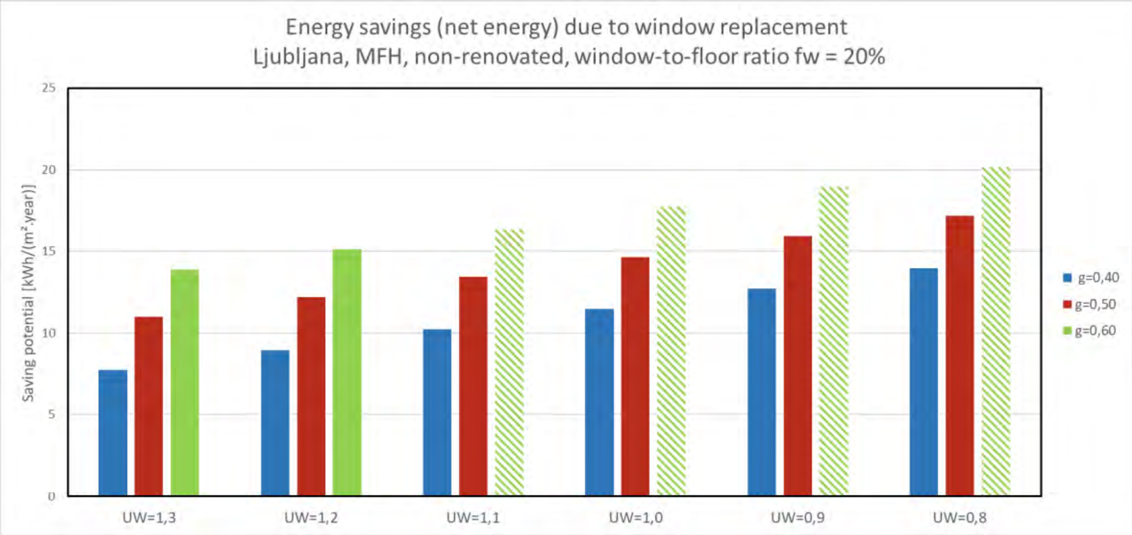


Figure D-147: Net energy savings for MFH, base case 1

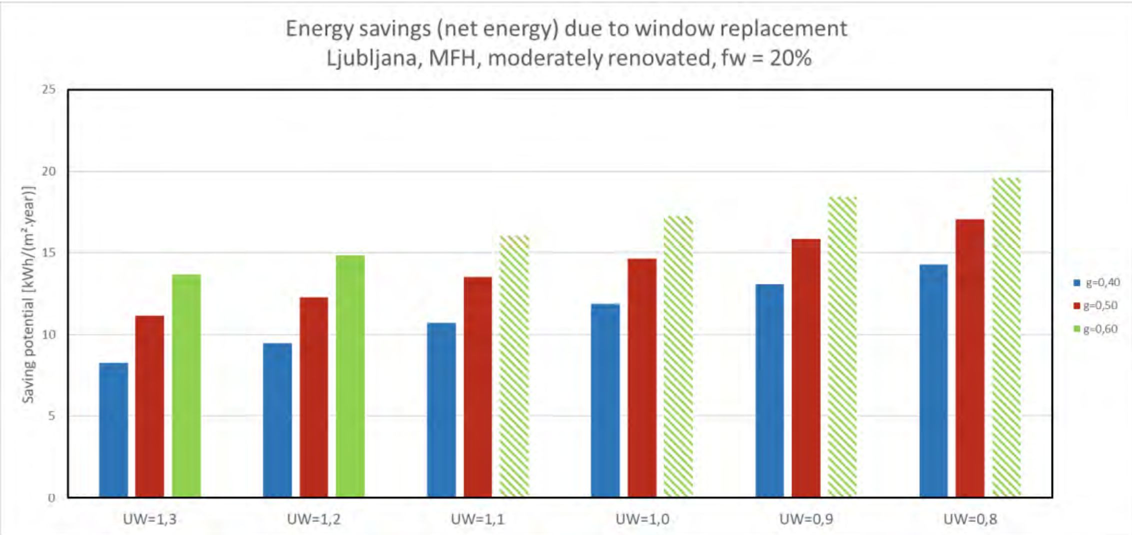


Figure D-148: Net energy savings for MFH, base case 2

D 25.2 Results national level (final energy and CO_2-savings)

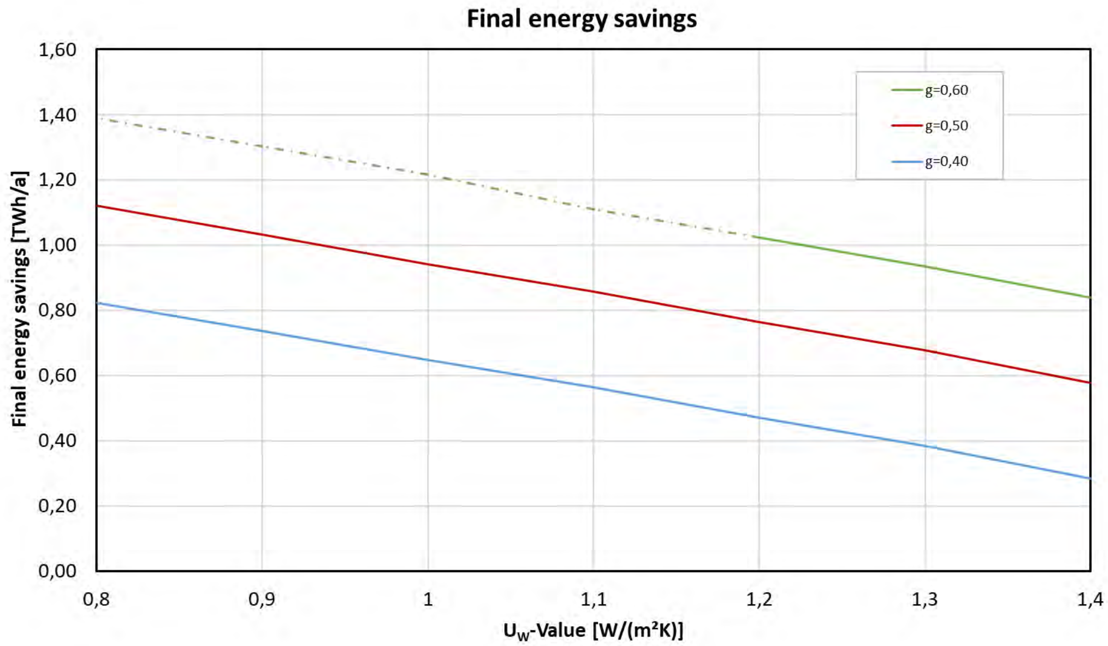


Figure D-149: Final energy savings Slovenia

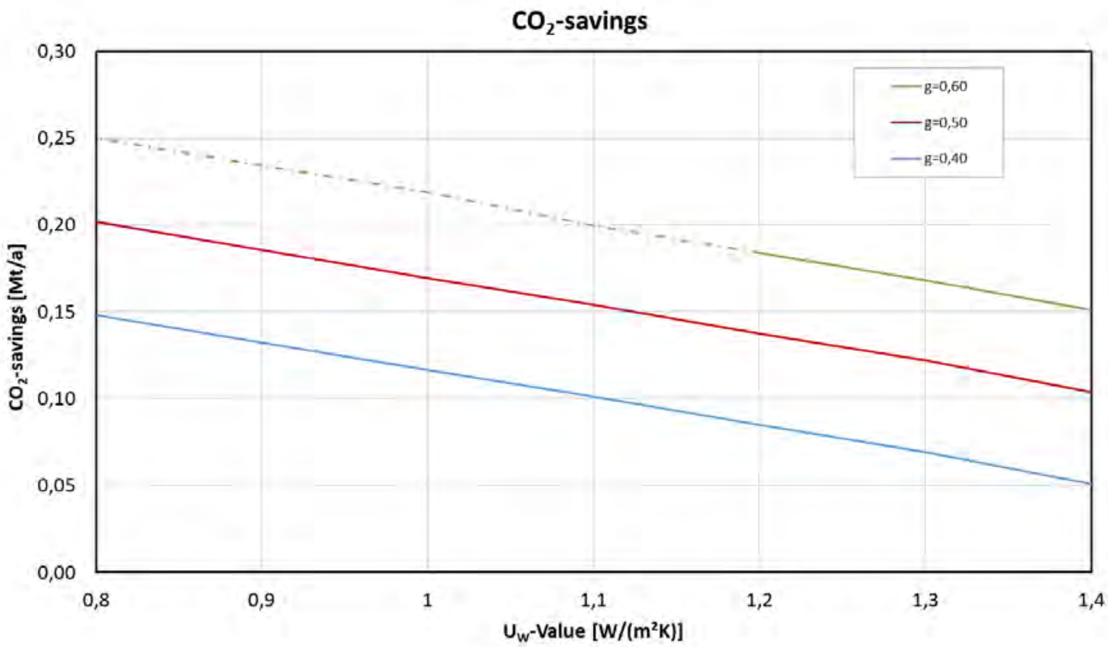


Figure D-150: CO_2-emission savings Slovenia

D 26 Spain

D 26.1 Results building level (net energy)

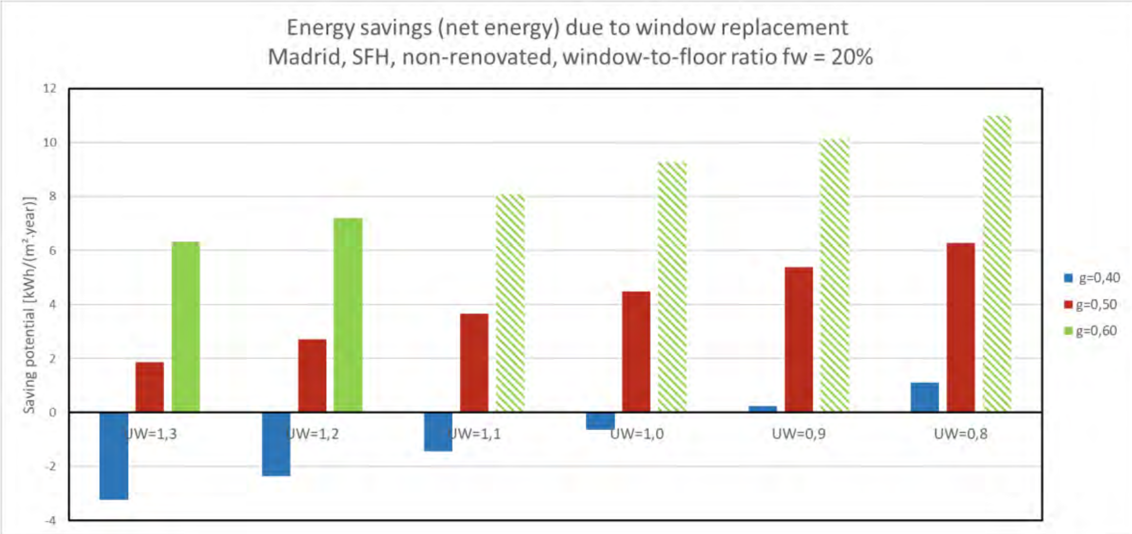


Figure D-151: Net energy savings for SFH, base case 1

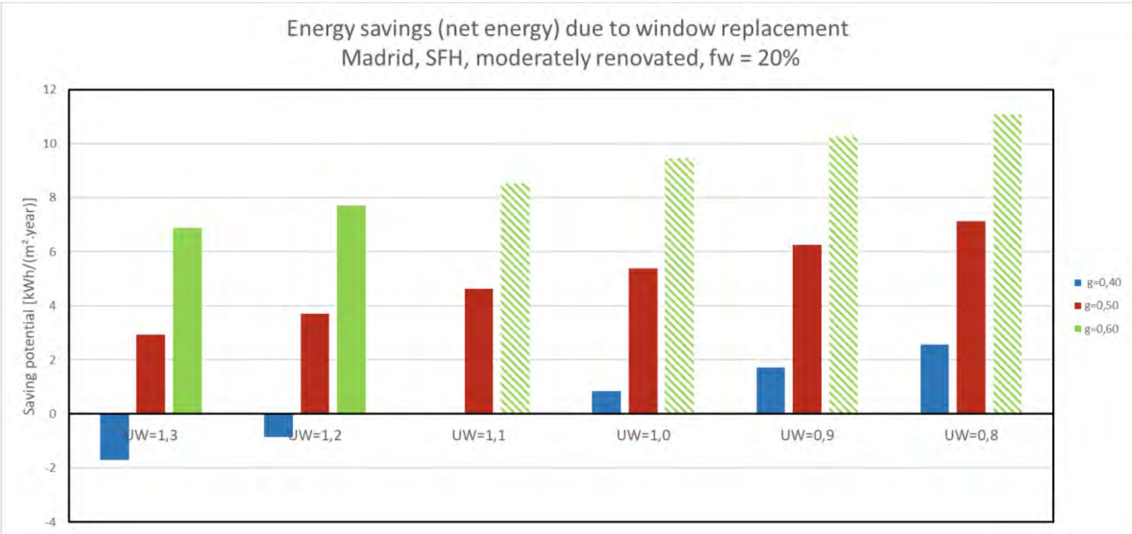


Figure D-152: Net energy savings for SFH, base case 2

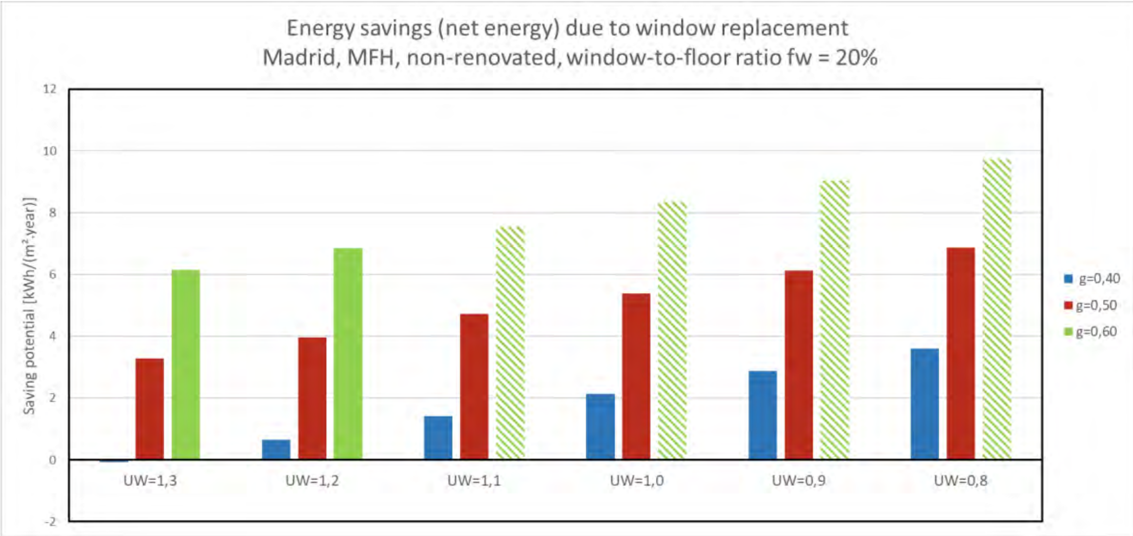


Figure D-153: Net energy savings for MFH, base case 1

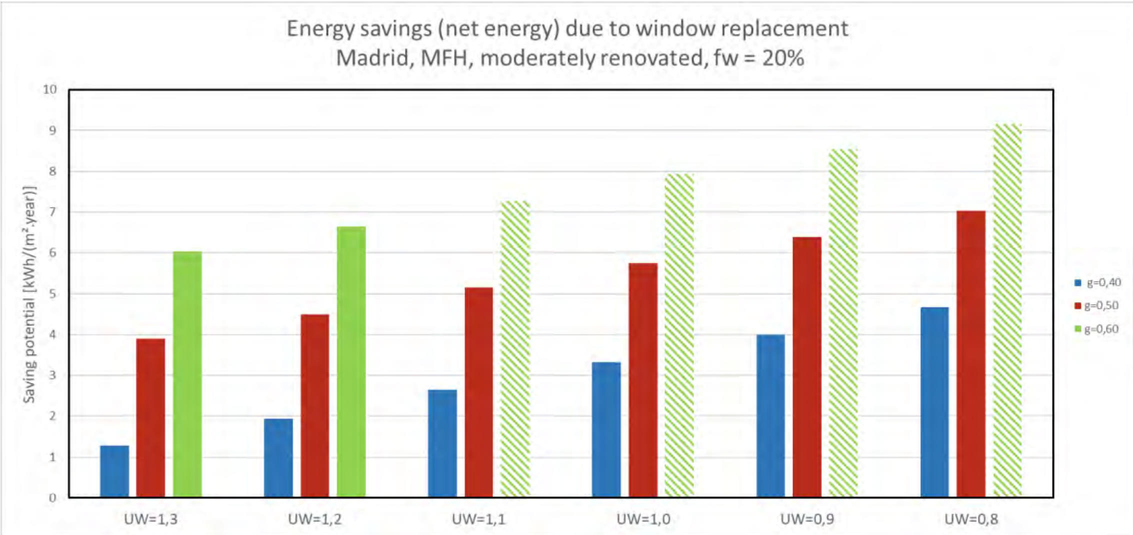


Figure D-154: Net energy savings for MFH, base case 2

D 26.2 Results national level (final energy and CO_2-savings)

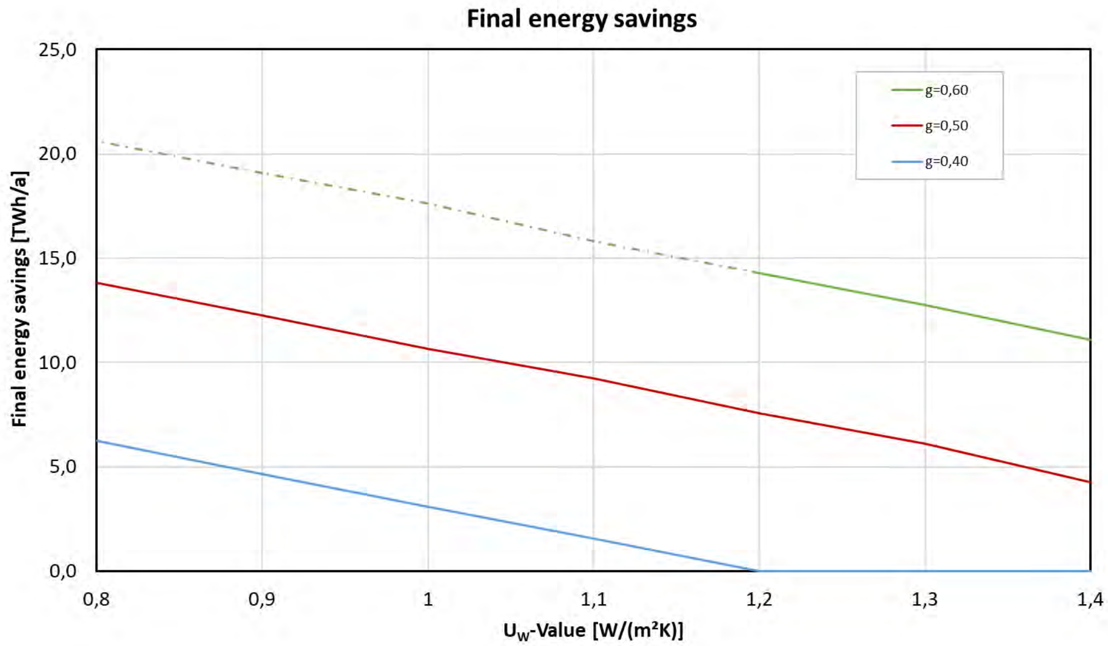


Figure D-155: Final energy savings Spain

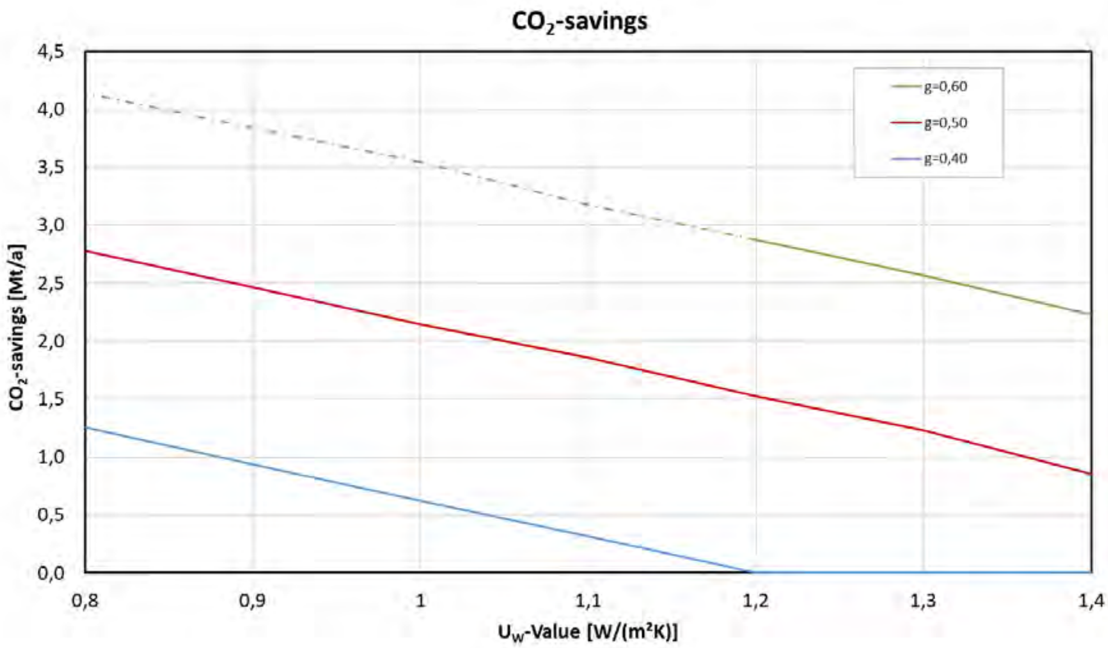


Figure D-156: CO_2-emission savings Spain

D 27 Sweden

D 27.1 Results building level (net energy)

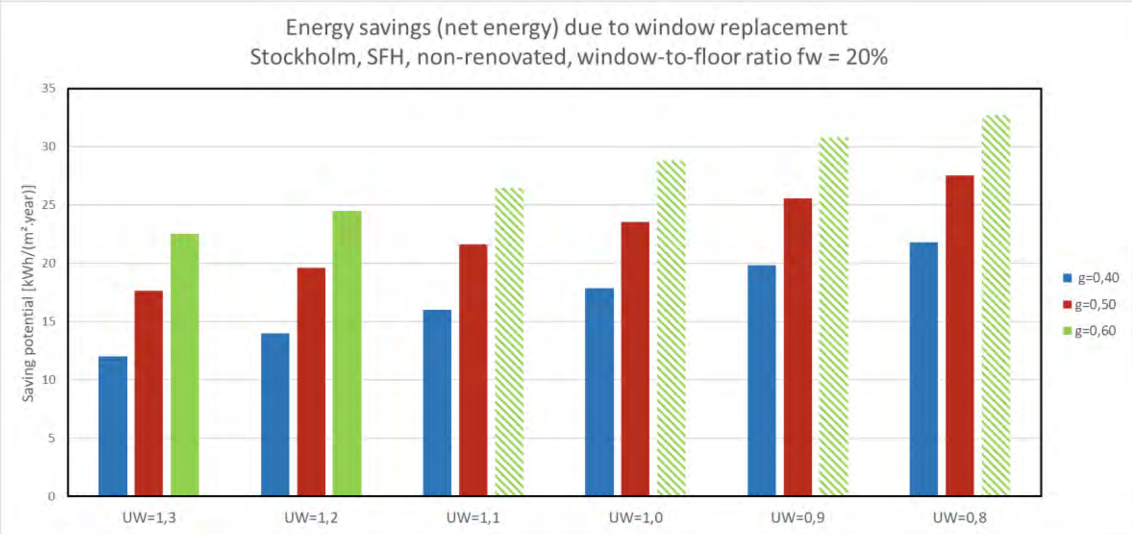


Figure D-157: Net energy savings for SFH, base case 1

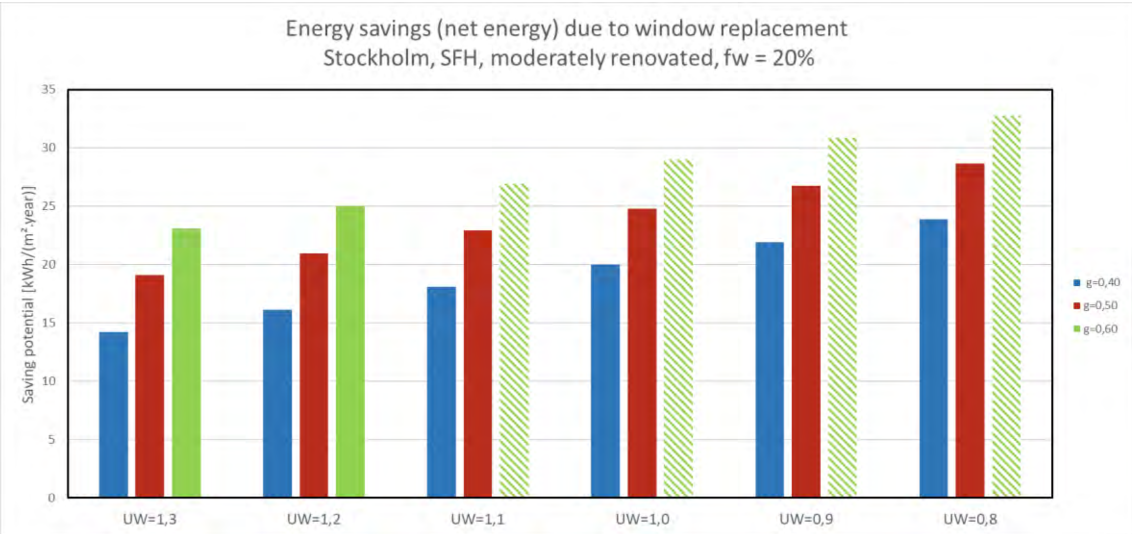


Figure D-158: Net energy savings for SFH, base case 2

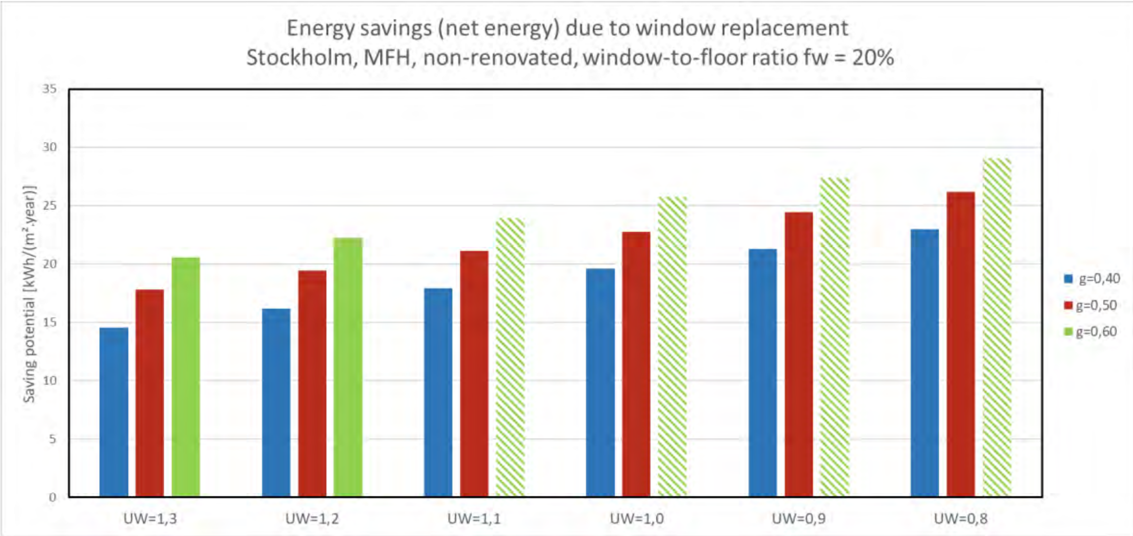


Figure D-159: Net energy savings for MFH, base case 1

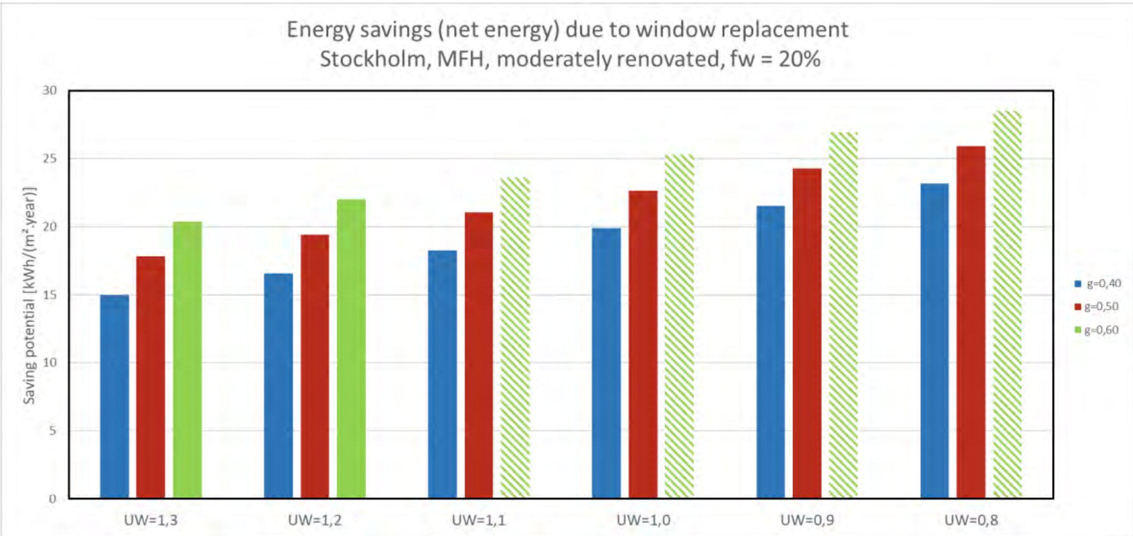


Figure D-160: Net energy savings for MFH, base case 2

D 27.2 Results national level (final energy and CO_2-savings)

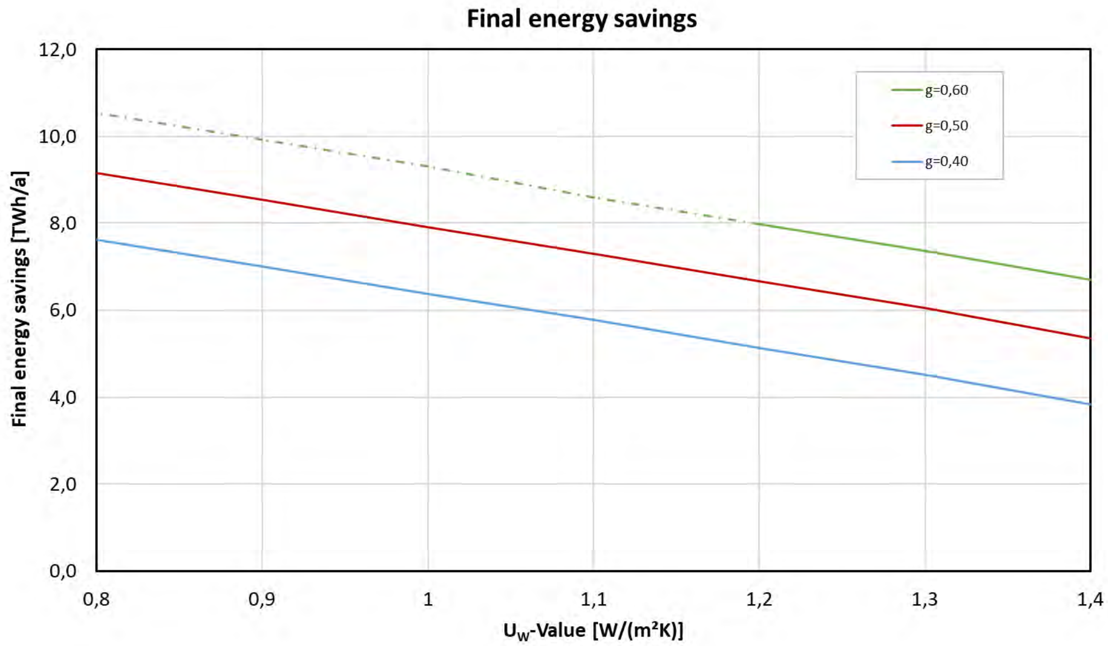


Figure D-161: Final energy savings Sweden

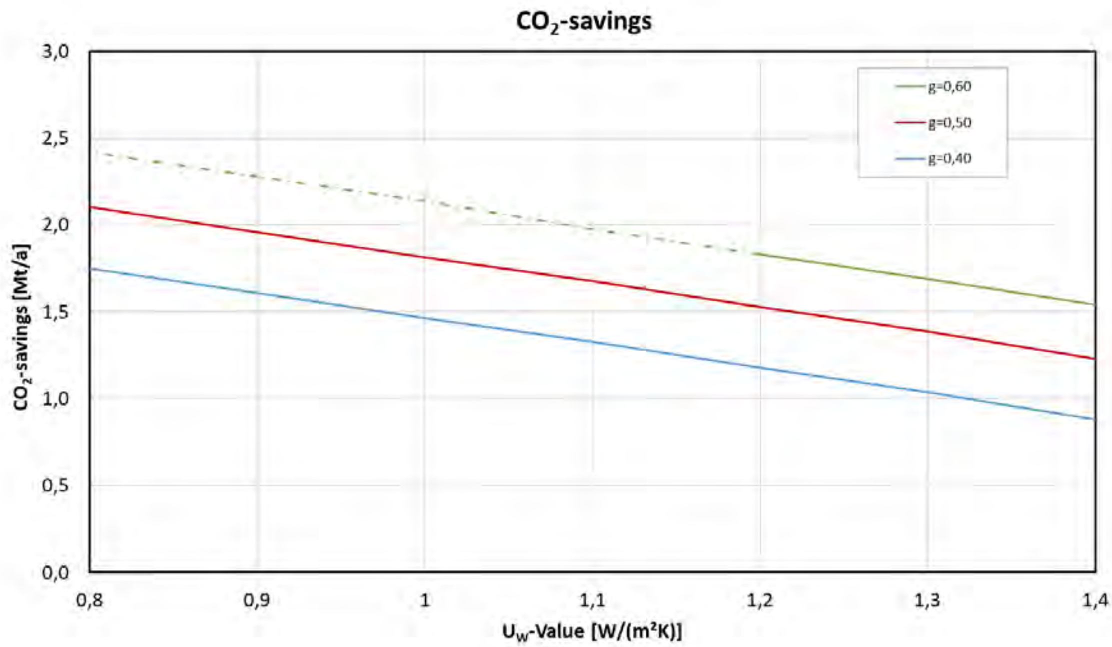


Figure D-162: CO_2-emission savings Sweden

D 28 United Kingdom

D 28.1 Results building level (net energy)

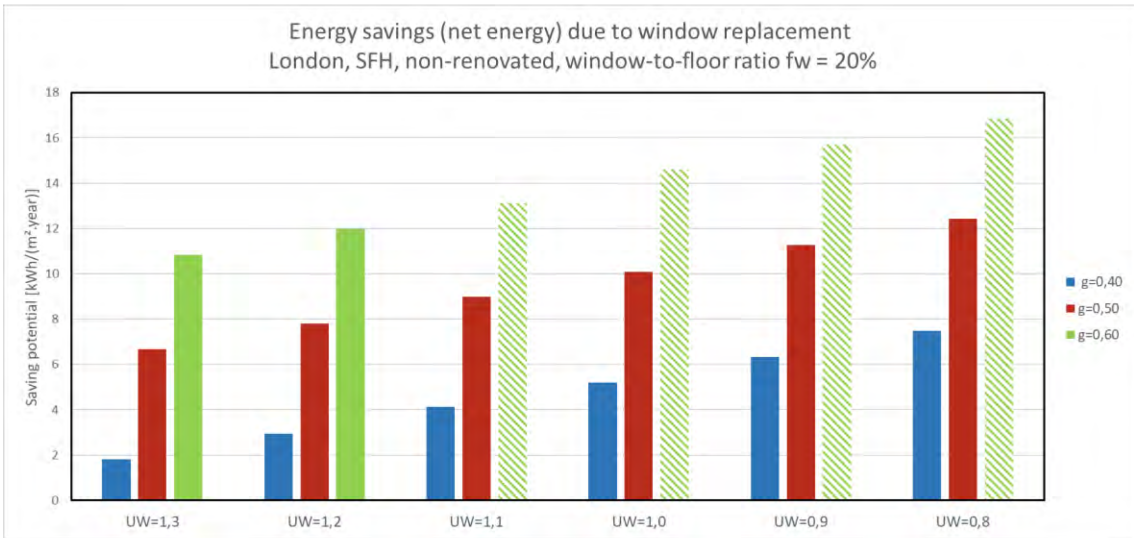


Figure D-163: Net energy savings for SFH, base case 1

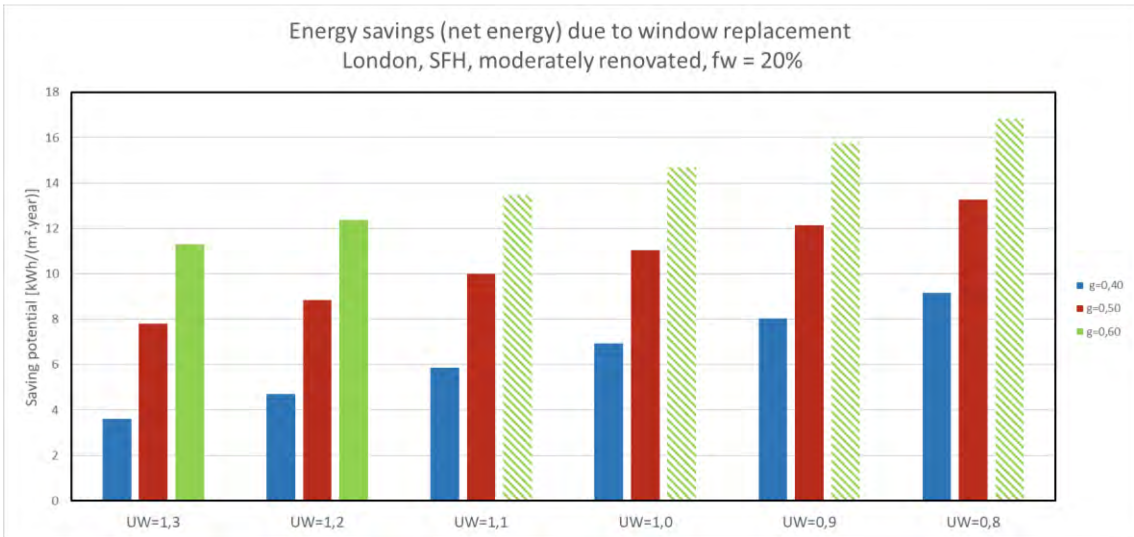


Figure D-164: Net energy savings for SFH, base case 2

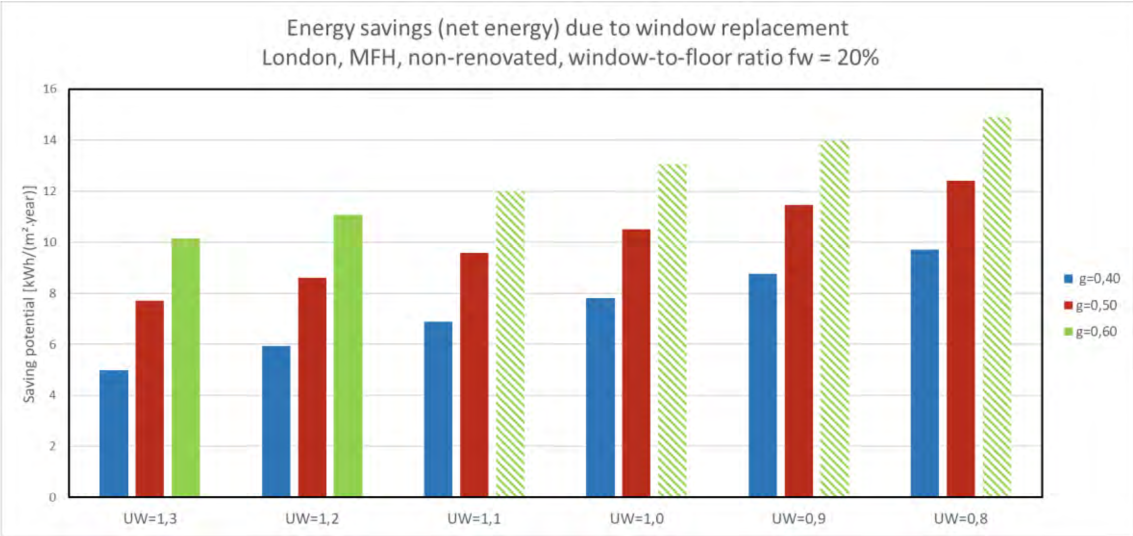


Figure D-165: Net energy savings for MFH, base case 1

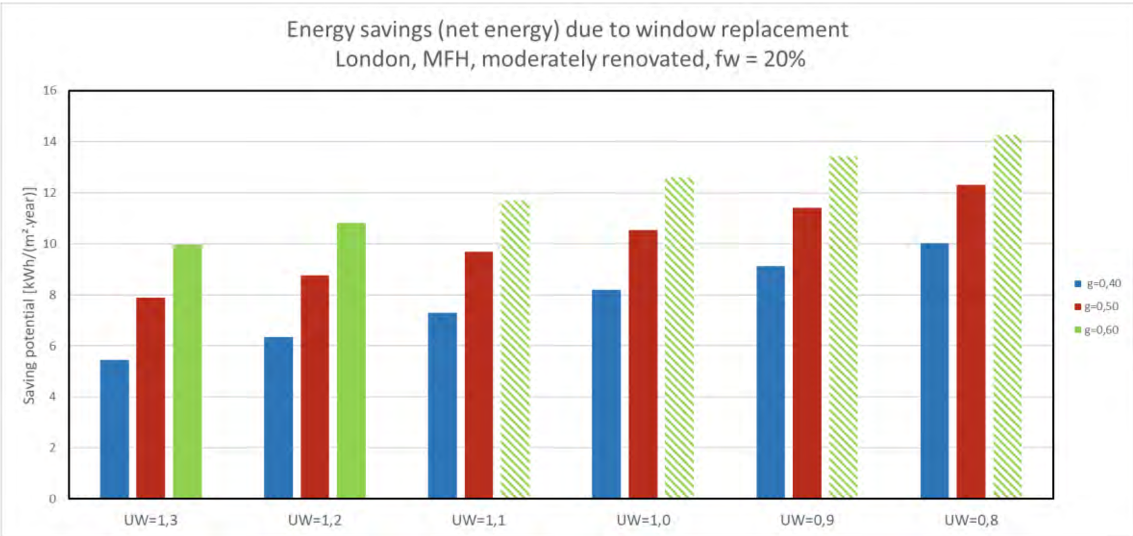


Figure D-166: Net energy savings for MFH, base case 2

D 28.2 Results national level (final energy and CO_2-savings)

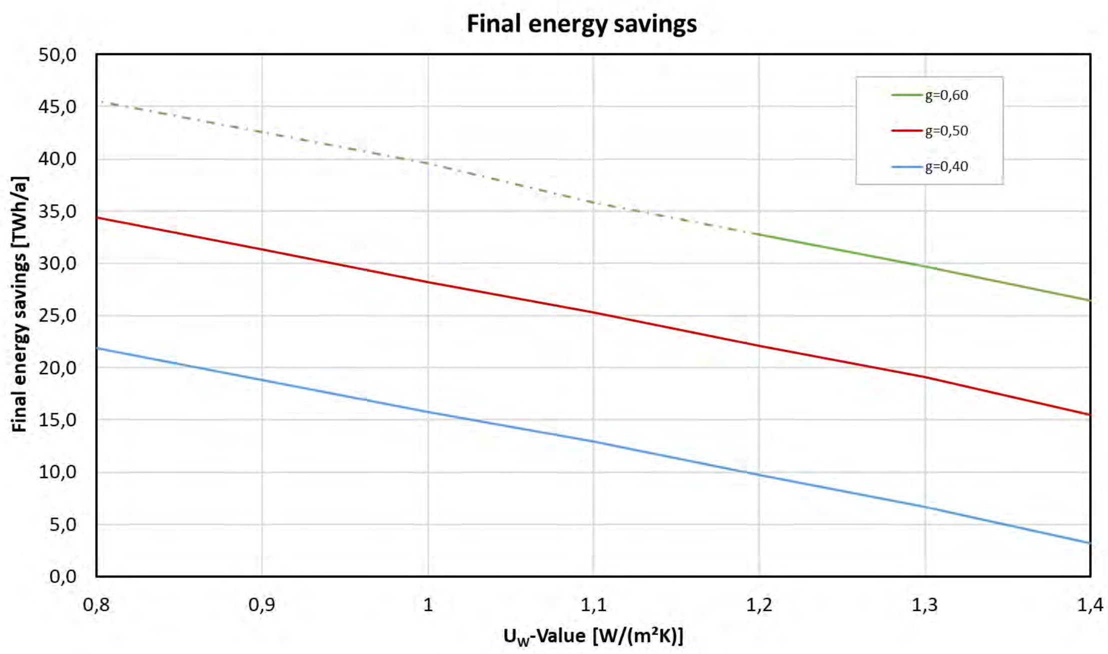


Figure D-167: Final energy savings United Kingdom

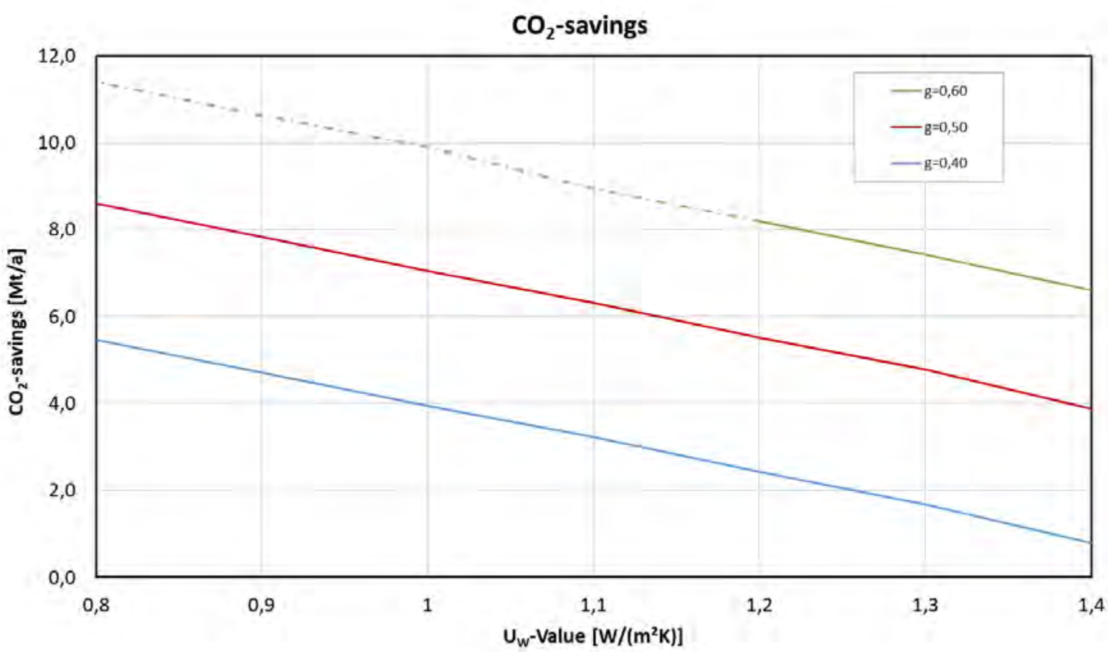


Figure D-168: CO_2-emission savings United Kingdom

Appendix E Savings, summed for EU28, Northern, Central and Southern Europe

E 1 Final energy savings

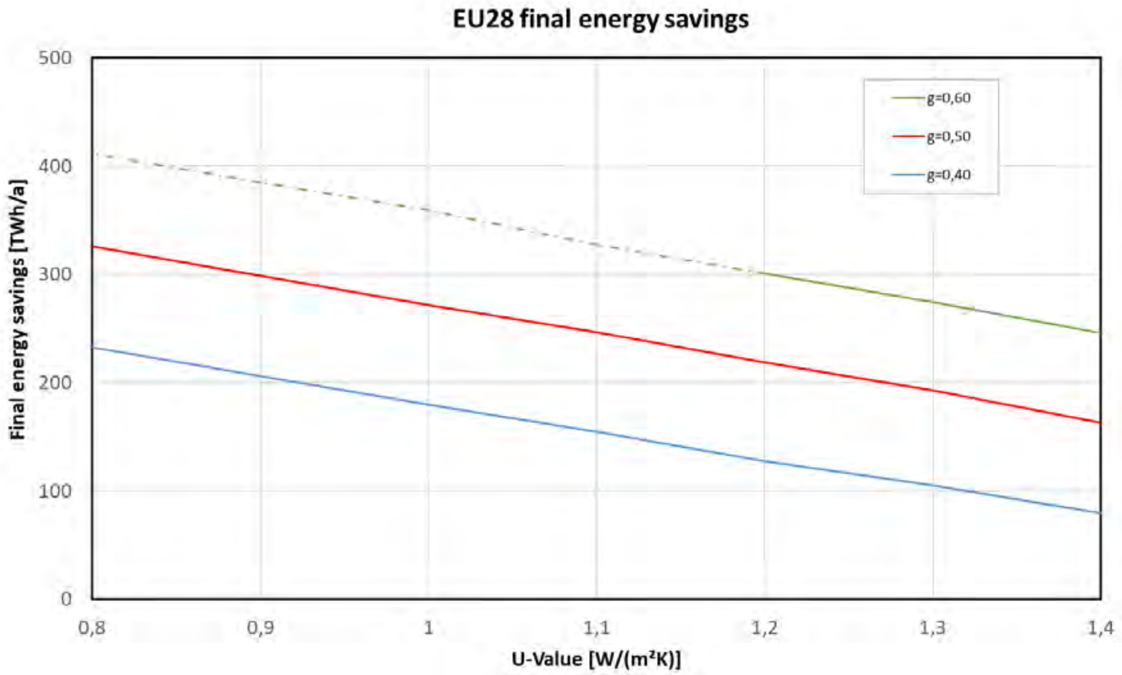


Figure E-1: Final energy savings EU28

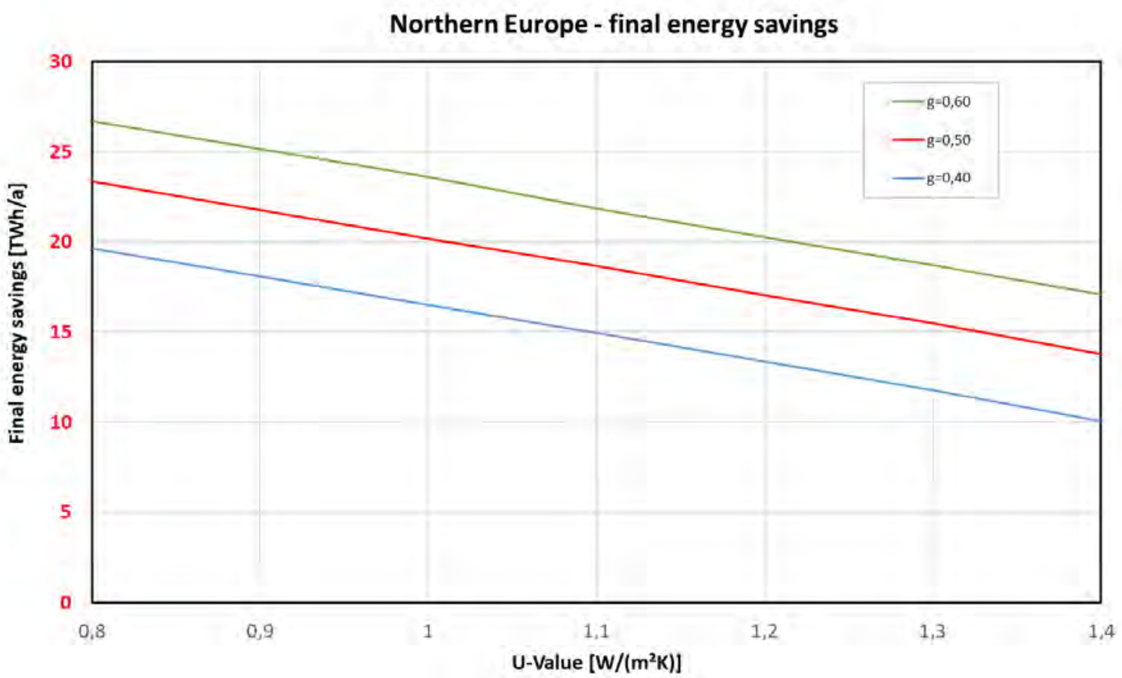


Figure E-2: Final energy savings Northern Europe

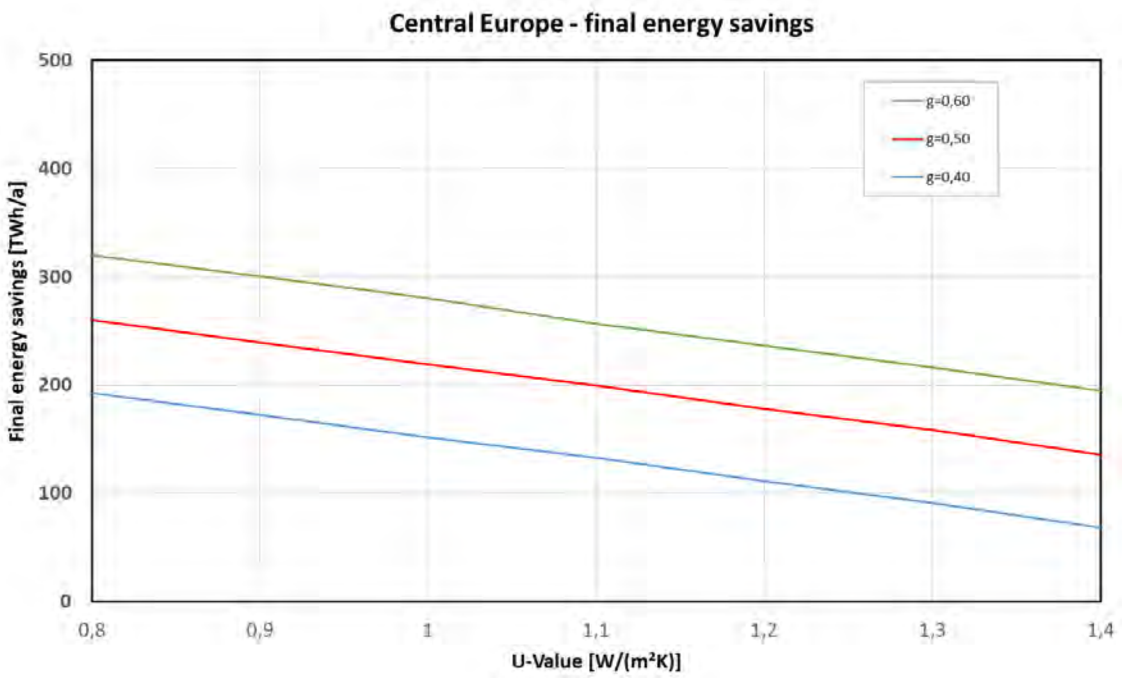


Figure E-3: Final energy savings Central Europe

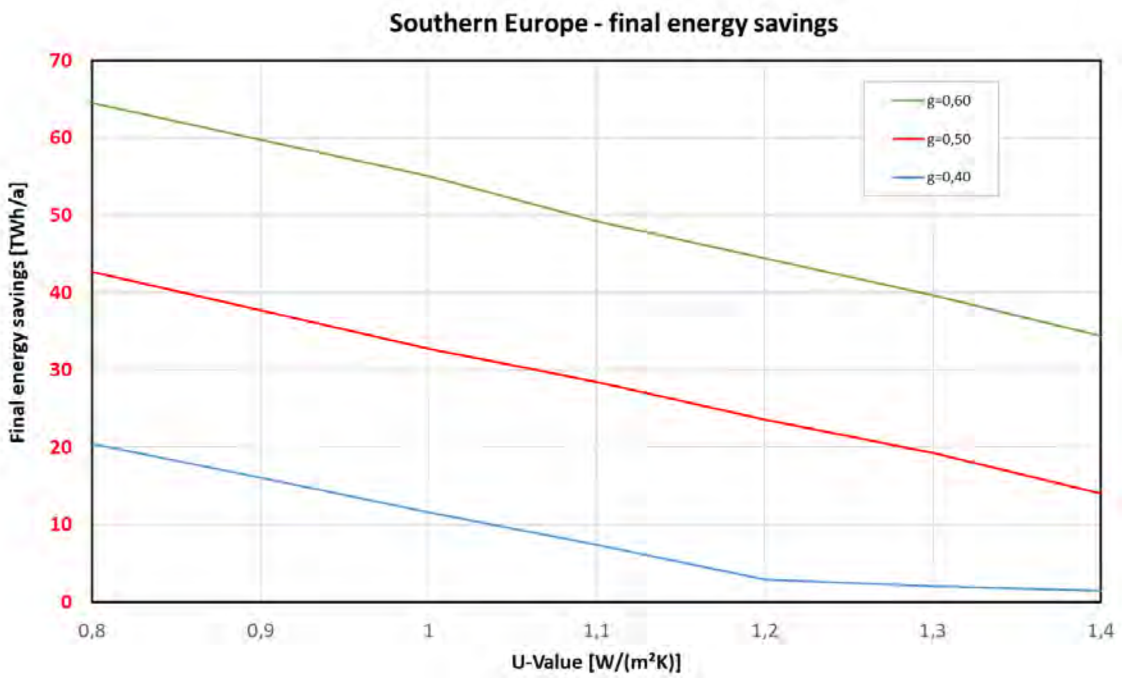


Figure E-4: Final energy savings Southern Europe